ENGINEERING MAGAZINE OF THE METALWORKING INDUSTRIES

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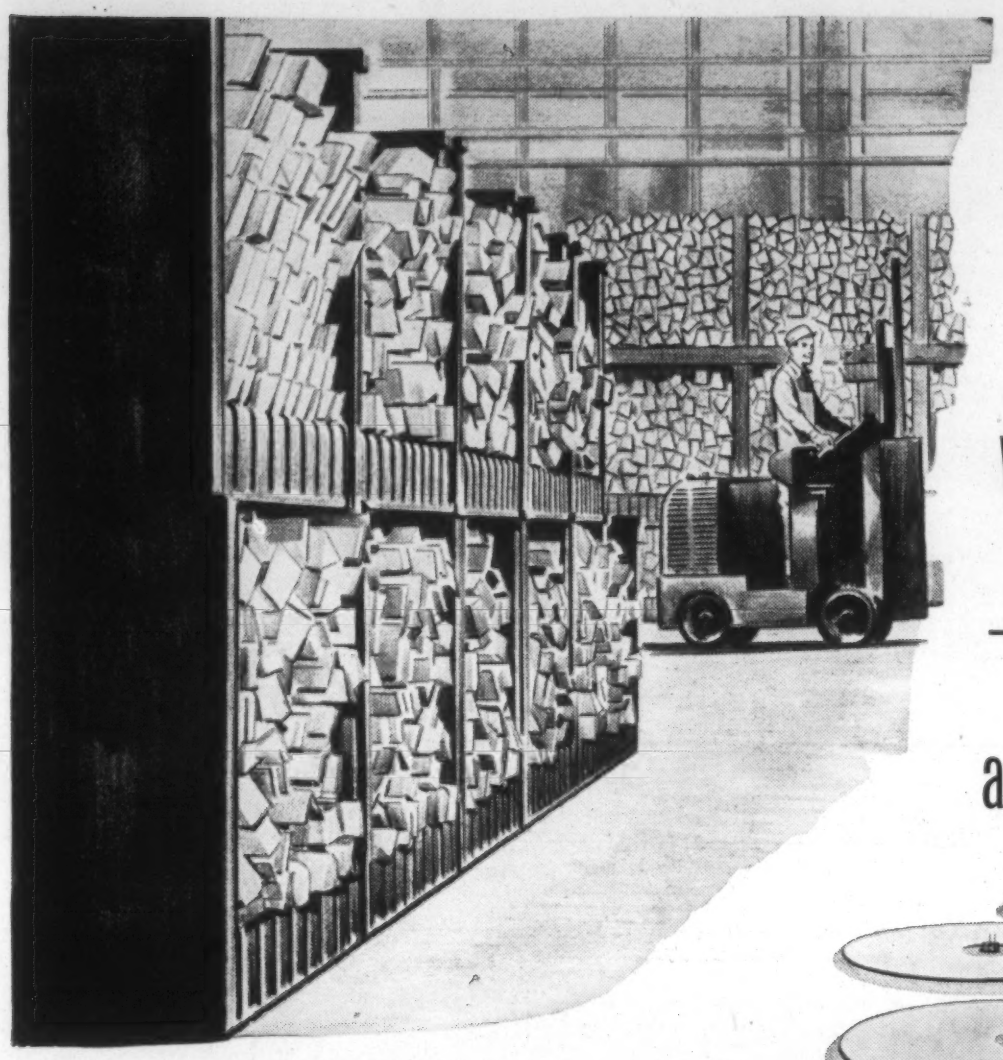

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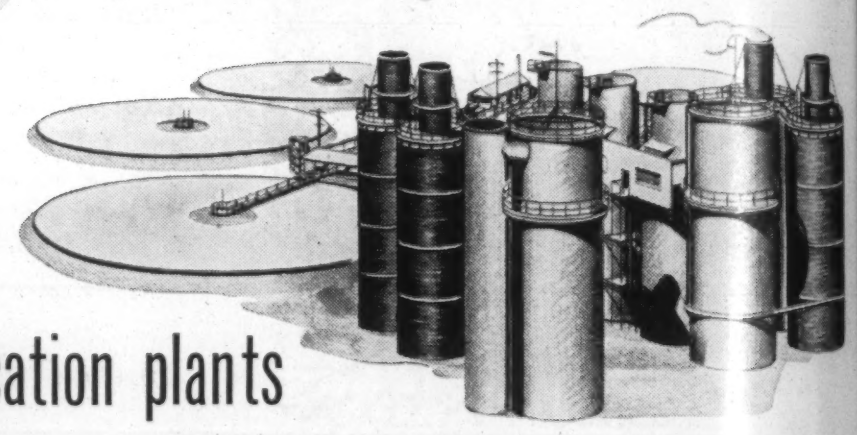

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METALS and ALLOYS

The Engineering Magazine of the Metal-Working Industries

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This Month

Magnesium Alloy Forgings — 688
A. L. RUSTAY, F. B. ROTE & C. E. WIRSING

Metals for Lightweight Construction—A Symposium 695
Introduction — 695
Low-Alloy Steels — 696
Stainless Steels — 698
Aluminum and Magnesium — 700

Soldering with Tin-Lead Alloys — 702
A. Z. MAMPLE

Extruding Large Nickel Alloy Tubing — 708
PICTORIAL

Refractory Concrete—II — 714
G. T. HADDOCK

Induction Heating for Forging — 719
H. A. STRICKLAND, JR.

Post-Formed Laminated Plastics — 724
AN ADDENDUM

MATERIALS FOR HIGH-TEMPERATURE SERVICE— 725
"Materials and Methods Manual" No. 4

ENGINEERING FILE FACTS

No. 75—Industrial Felt — 741

No. 76—Standard Gage Sizes — 743

No. 77—Anti-Friction Bearing Maintenance — 747

Every Month

The Production Front — 615

Editorials — 683

Shop Notes — 749

Engineering Digest — 757

Manufacturers' Literature — 826

News — 833

Meetings and Expositions — 856

Advertisers and Their Agencies — 904

Blueprints — 906

Next Month

Our April issue will feature articles on Wood as an Industrial Material, Casting and Machining Iron Crankshafts, Specifying Steels for Welding, Deep-Drawing Magnesium, Continuous Heat Treating of Shells, plus a 16-page Materials and Methods Manual on Permanent Mold Castings.

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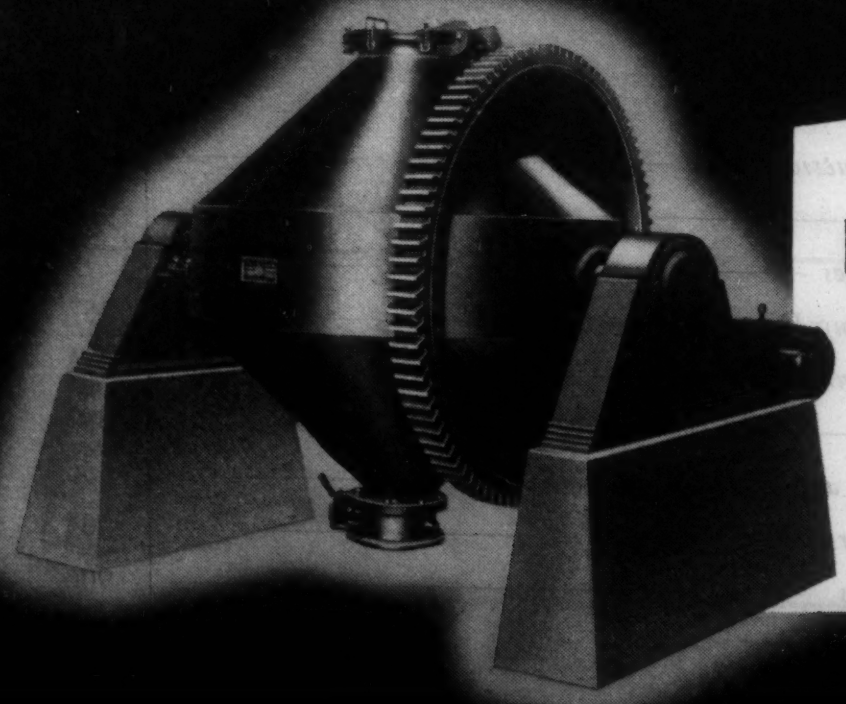

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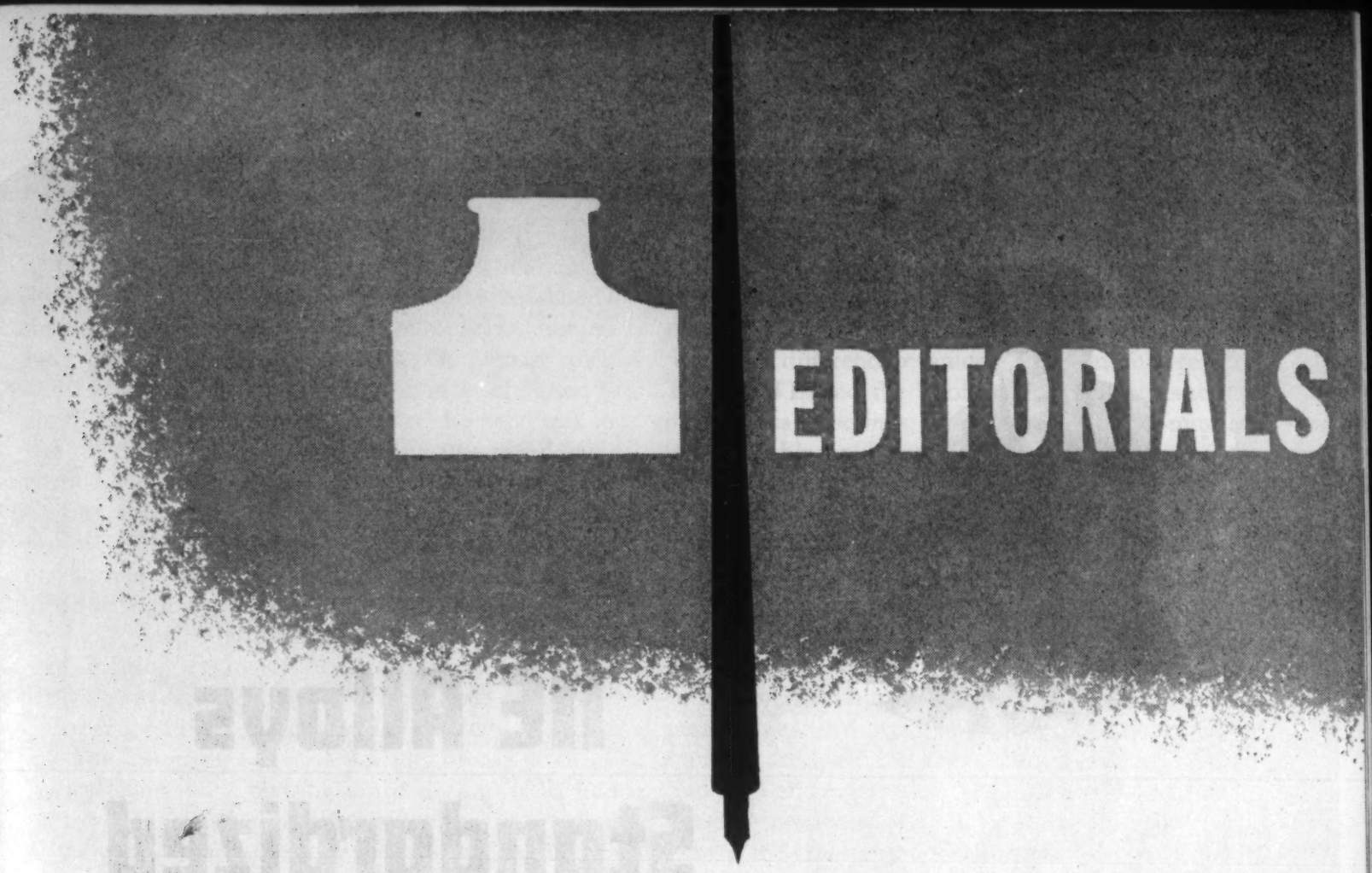

The War Metallurgy Committee

We have recently spent several months in Washington doing some special editorial work for the War Metallurgy Committee. We naturally had a splendid opportunity to view the committee from the inside. While there are many things into which we had an insight but which we cannot discuss, we can say something about the organization as a whole.

The research work in metallurgy and some allied subjects which this committee has been and still is doing is broad in its scope and highly important in its ultimate results. Broad because it embraces many diversified problems of vital importance to the war effort and later to industry in general. Important because its results, when fully made public, will be of great value to the nation as a whole.

It can be confidently stated that during the comparatively short life of this committee, more problems have been undertaken and solved than would have been initiated under ordinary peacetime conditions. As a result progress in metallurgical engineering research has been advanced several years—even more has been achieved than during 10 to 20 years under ordinary conditions. The conclusions of the various research projects have been based on a research program of the highest technical authority. It is unfortunate that most of these data cannot now, for military reasons, be made public. When, however, they are broadcast, their high value will be readily recognized.

If and when the life of the War Metallurgy Committee comes to an end, as it probably must, we hope that some arrangement can be authoritatively made to officially continue the research work. We hope also that all the results that have been achieved can be made public for the benefit of industry and if necessary for another war, which we hope will never come.

When the story of the committee and how it functions is written, it will be one of intense and unusual interest. Great credit will go to the man or men who conceived this organization—a concept which many at the time said would never work out, involving as it did many more or less conflicting interests and aims. It has worked out—and it can be safely asserted that never has there been a more productive and cooperative metallurgical engineering accomplishment.

—E.F.C.

What! No Conventions?

To the long list of shortages that have lengthened our faces and strengthened our souls in the last few years must now be added the impending blight on conventions—a "commodity," it must be admitted, in which the technical man has been all too prone to over-indulge.

Those of us who had the "convention habit" will probably have to go underground (as at Cleveland

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in October, 1944) or patronize the black market to find relief from our craving. There may be shoddy substitutes with ripe Turkish atmospheres, not so fully packed as our old favorites. Or perhaps they will ration the small supply on the basis of "essentiality," in which case you can expect the habituées to jam all corridors, leaving a howling unsatisfied mob outside, the same as when a consignment of a hundred cartons of Chesterfields is put on sale with 10,000 visible customers clamoring for one pack each. Or maybe some friend will tell you about a place on the other side of town where you can get tickets (at double the registration rate) to a secret conclave of cold treating engineers in Hot Springs next July, without having to endorse your program.

Every cloud has a silver lining, though! Even if our absorption of a certain amount of technical information is thus painfully postponed, we will find ourselves in better health in the Spring and the Fall of the year (the most critical periods, outside of Summer and Winter, we are told) for having enjoyed an average of 7 hours peaceful sleep rather than the conventioneer's stormy 3. And in our protracted and untroubled April and October slumbers we can laugh vengefully at that modern monstrosity, The Housing Committee, and the fate that befell it at last!

Seriously, though, some technical meetings are highly valuable in their actual contribution to an early Victory and others are not. We are not competent to differentiate among them in this respect. The A.I.M.E. and the Tool Engineers have cancelled their annual meetings; The Open-Hearth Committee will probably hold two regional meetings instead of one national gathering. A.S.T.M. has cancelled its plans for both Committee Week in March and the annual meeting in June.

The Metal Congress and Exposition in October is still an open question and a big one at that, for that meeting is one of the largest industrial conventions in the country and makes an obviously enormous technical contribution to the war effort. Although we suggest it reluctantly, perhaps the exposition could be omitted this year but the technical meetings be retained to make possible a 1945 Metal Congress under present conditions. Or (we can dream, can't we?) maybe the transportation situation will be easier by October and the restrictions will have been lifted.

Anyway, historians will someday say that early in 1945, in the midst of a terrible war, a great peace settled upon America. And you and I will know the reason why!

—F. P. P.

Eiffel Towers Everywhere

One of the features of the Paris Exposition of 1889 was the Eiffel Tower, an iron structure designed by A. G. Eiffel. It was at that time the tallest building erected by man; its height was 984 ft. For many years thereafter New York's skyscrapers were forced to advertise themselves as "the tallest *habitable* structure," etc., in the race to be the biggest something-or-other.

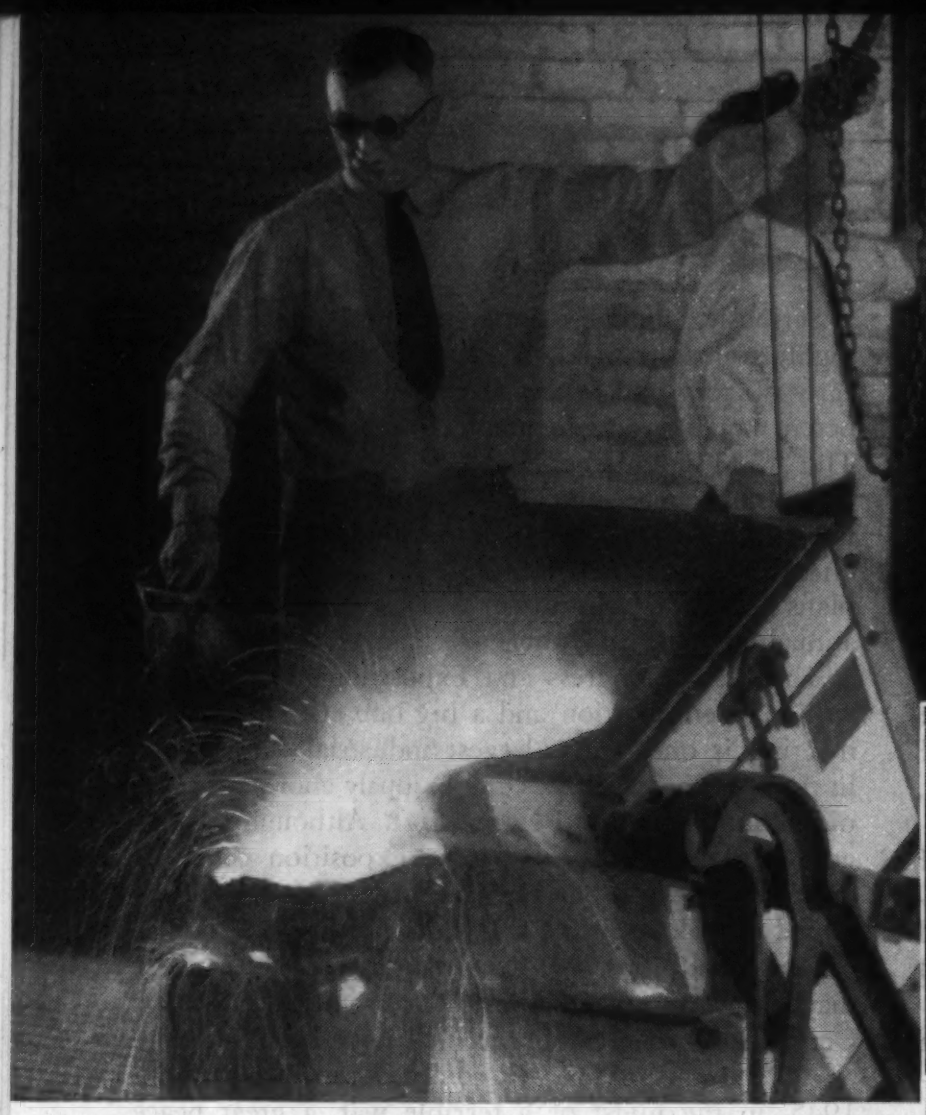
In the half-century that has passed since its erection, the world has produced better steels, better materials of all kinds, and construction and design engineers have learned a thing or two. We have seen the Chrysler Building (1046 ft.) and the Empire State Building (1250 ft.) in New York outclimb the Eiffel Tower, while No. 60 Wall Tower (950 ft.) and the Bank of Manhattan (927 ft.) snap at the leaders' heels. But another group of structures is reaching Eiffel Tower height. These are the radio broadcasting towers.

With the completion of a 1050-ft. tower reported from Moscow, radio towers have now outclimbed the Paris wonder of past decades. In the United States these skeleton skyscrapers have reached to within Eiffel Tower range with the Yankton, S. D., structure of 930 ft. and the Oklahoma City tower of 927 ft. Nashville, Tenn., (878 ft.) and Cincinnati, O., (815 ft.) are approaching them. All over the world, the radio industry is building higher and higher.

These modern Eiffel Towers must be well built. Many are erected in regions frequently swept by hurricanes, when wind velocities have been recorded exceeding 126 miles per hr. Florida stations have been doubly troubled in some cases by requiring construction to meet high wind loads, with soil not well suited to solid foundations. In a recent storm a concrete base was lifted out of the soft ground by the steel member it was supporting. Builders have found that they must frequently utilize medium-carbon steels instead of the mild steel that was formerly standard for construction work.

An air-minded age naturally places stringent visibility requirements upon such structures. Towers to 200 ft. high must show two fixed lights at one-third height, two at two-thirds, and a light at the top. Those from 200 to 400 ft. must show a flashing code beacon on top in addition to the lower fixed lights. If 400 to 600 ft. high, the tower must have fixed lights at one-fourth height, two flashing beacons at half-height, fixed lights at three-quarter height, and a flashing beacon on top. Painting must be in international orange and white bands, with red bands at the top and the bottom one-seventh. Towers above 600 ft. must meet the requirements of the 600-ft. group.

—K. R.



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Making small casts of steel is one phase of Inland's continuous research for better methods of producing steel, and for better steels *that* will make better products.

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Are We Being Out-Engineered?

an Editorial

Engineers must be hearing with mixed emotions the growing chorus of criticism of American fighting equipment, the tenor of which is to the effect that we are being consistently out-engineered by the Germans in the design and performance of the weapons of war. This arises from a general awareness of several "sensational" German weapons, at the same time that it reflects a persisting impression that the Germans are super-scientists and super-engineers with a special gift for invention and development lacking in others, including ourselves.

The present superiority of German tanks is accepted by some as proof of this. It is also true that the Germans either invented, pioneered or have more effectively developed the robot bomb, the rocket bomb, the jet-propelled plane, self-propelled artillery, magnetic and sonic mines, rocket-firing planes, etc. and that they have demonstrated a notable ingenuity in extending their critical metal supplies by smart materials engineering and substitution.

But is it true that we are being out-engineered and that the enemy's technical men are smarter than we? If so then America is in a bad way indeed, for we will need something better than inferior engineering skill if we are to speed Victory and then solve the technological problems involved in developing new industries and meeting international competition after the war.

Actually we are not being out-engineered, but we are being out-organized and out-expedited. It is time therefore to stop talking about the alleged superiority of German engineering and, instead, to start utilizing our own tremendous engineering potentialities more effectively than we have done to date. There is plenty of evidence, for example, in such American developments as the super-bombers, radar, the Garand rifle, submarine detection devices, the ubiquitous jeep, the "portable" piers used in Normandy, the gyroscopic tank-gun stabilizer, the phosphorus bomb, amphibious attack equipment generally and our own highly successful materials-conservation program (as well as certain still-secret weapons) that the Germans have no monopoly on inventive skill and originality. In addition we have a unique and characteristically American genius for mass-production engineering, which has enabled us to more than offset the enemy's years of engineering regimentation with a "quantity" strategy that telescopes time in our favor and is emerging as the heavily decisive factor in this war.

Once our scientists and engineers attack a problem they solve it at least as quickly and effectively as would their opposite numbers among the enemy. *But they must first know that the problem exists!* Engineers in industry and even in Ordnance cannot put their brains to work on specifically needed new weapons or on modifications and improvements of old without some disclosure of the need in each case and a request for help in remedying it. Advices from the combat areas and from Washington indicate —in contrast to the German method of having technical observers at the front return and directly participate in the ultra-fast development of new weapons and needed improvements—that the expressed needs of the GI soldiers, the expert observations of unofficial civilian and military observers and the suggestions of competent engineers in industry usually become lost or entangled in official inertia and red tape and that expeditious investigation and approval of a good idea is virtually unknown.

Our top Army officers must courageously provide organizational means for more speedily applying the lessons of combat to the improvement of our present weapons and the development of new types. We have in America all the inventive brains and technical skill required to out-engineer our enemies. What is still needed is the will on the part of some military leaders to utilize them in every possible way and with the utmost dispatch.

FRED P. PETERS

A Materials-and-Methods Article A major wartime development of outstanding post-war significance is the improvement in methods of making magnesium alloy forgings, whereby forgings of better quality and of greater design possibilities than were previously available can now be produced. The improved practice, resulting mechanical properties and some interesting recent applications are described in this article.

Production and Properties of

Magnesium Alloy Forgings

by A. L. RUSTAY, F. B. ROTE, and C. E. WIRSING

Mr. Rustay is assistant chief metallurgist of the Wyman-Gordon Co., Worcester, Mass. Messrs. Rote and Wirsing are members of the metallurgical staff.

BECAUSE OF THE EXPANDED capacity for the production of magnesium during the present war, and the curtailed need for the product of the number of plants built during the war, large quantities of magnesium alloys are now available for new applications. Since most applications for castings have been cared for in the past, the one major remaining outlet is in forgings which, to date, have been used to a very limited extent.

Captain P. W. Bakarian, U.S.A.A.F., who made a survey of American and British magnesium production and fabrication plants, reported that only a small fraction of the total magnesium alloy in present use is in the form of forgings. In December, 1942, the total production of forgings in the United States and England combined was only 10,400 lb., while 5,150,000 lb. of castings were made. This situation has been modified somewhat in the more recent past. The utilization, however, of magnesium forgings remains at a relatively low level.

The Germans, on the other hand, have made rather extensive use of magnesium forgings in aircraft, with attendant savings in assembly man-hours and adequate service performance. An excellent example of a German die forging is the JU-88 engine mount shown in Fig. 1. This was made of the high strength press forging alloy, AM58 (ASTM9), in, it is surmised, a hydraulic press of 15,000 to 20,000 ton capacity. The over-all length is 44-13/16 in. and the width is 14 in. with a projected area, excluding flash, of roughly 275 sq. in.

This article is based on research work done in part under the supervision of the War Metallurgy Committee as Project NRC-552 for the Office of Production Research and Development of the WPB. Permission for publication has been granted by the OPRD. Mr. Rustay was the official investigator.

The project had two primary objectives: (1) To produce and test, under static and dynamic conditions, a number of forgings from the standard forging alloys to obtain data upon which designers, particularly of aircraft components, can base design calculations in considering the application of magnesium forgings to replace heavier metals. (2) To obtain data on the forgeability of the standard American forging alloys, which will assist other forge shops in the design of proper dies and the metallurgical control of the alloys during forging.

This article is concerned principally with the results obtained in experiments related to forgeability and metallurgical control.

Magnesium and its alloys solidify in the close packed hexagonal system. Because of this the ductility is low, and the restrictions on the amount of work which may be done on the metal or its alloys at room temperature are quite severe; excessive work produces failure by shear.

At room temperature and up to 437 F (225 C) only one slip system is operative, this being along the basal planes. At 437 F (225 C) a second or multiple of systems become operative, and slip failures at temperatures above the critical reveal pyramidal planes. At about 575 F (300 C) the elongation possible along a basal plane is about three times as great as at room temperature. Still further increases in temperature permit greater ductilities until, at temperatures approaching the eutectic temperature for the alloy in question, the ductility may be as great as nine

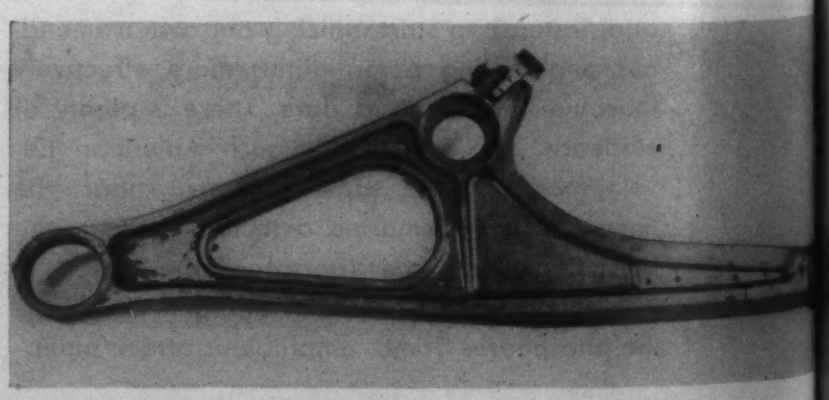


Fig. 1. A JU-88 German engine mount made as a die forging of alloy AM58.

times room temperature ductility. No fundamental data have been obtained along these lines in the present project, since its primary objective is to produce and obtain mechanical properties of forgings of all the standard American forging alloys. However, the ductility changes effected by varying temperature from room temperature to the eutectic exert a marked influence on the possibilities of forging the magnesium alloys.

Representative Forgings

A large number of forgings have been made in all of the standard forging alloys in dies originally designed for aluminum. A group of these forgings showing a widely different type of grain flow is shown in Fig. 2. The top center forging, an aircraft piston, demonstrates extreme metal flow to fill the skirt sections and the small waffle grid in the inside of the dome. The "T" shape forging to the right and below the piston is made from a 3-in. multiple. This is another type of metal flow.

The small impeller on the right side of the photograph demonstrates considerable flow into high thin ribs, while the other forgings demonstrate intermediate degrees of flow to relatively thick ribs and with or across the flow lines in the original extruded stock.

All of the above forgings, except the piston, were made by a combination of operations involving blocking in the press and finishing in the hammer. The piston was made in a 2,000-ton hydraulic press.

Attempts have been made to produce magnesium alloy forgings containing 6 to 8.5% Al by hammer operations exclusively; however, these have not been very successful due to the tendency of these alloys to shatter under rapid work. It is, therefore, necessary to use the press or a combination of press and hammer.

Press vs. Hammer Forgings

Certain of the standard American forging alloys have been developed for hammer forging, while the others, which were developed on the basis of high strength, are press forging alloys. Table I presents the nominal specified compositions of the five common alloys. In hammer forging operations the AM3, AM52, and AM65 alloys handle very much the same, while AM57 is more difficult to forge. AM58 is the most difficult to forge of the standard alloys. The difficulty in forging is related, roughly, to the aluminum content of the alloys, which also determines the properties of the final forging to a large extent.

The hammer forging alloys in Table II possess similar properties and are considerably weaker than the AM57 and AM58 alloys, which contain more aluminum and have been developed for press operations.

Examples of the relative forgeability of the three classes of alloys; the three lower strength alloys being

Fig. 2. A group of representative magnesium forgings made in this country.

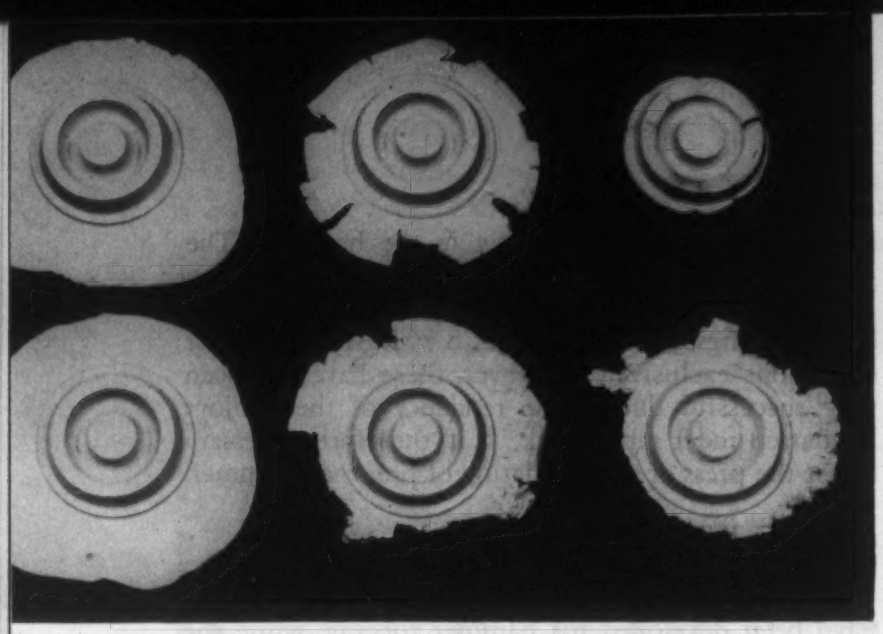


Fig. 3. Piston forgings of magnesium alloys, upset, blocked, and finished in the hammer.

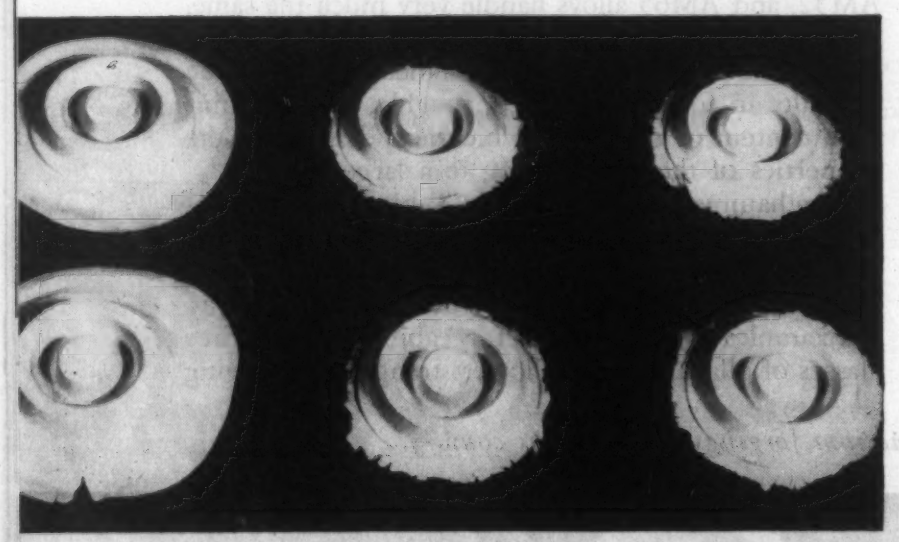


Fig. 4. Piston forgings, upset and blocked in the press and finished in the hammer.

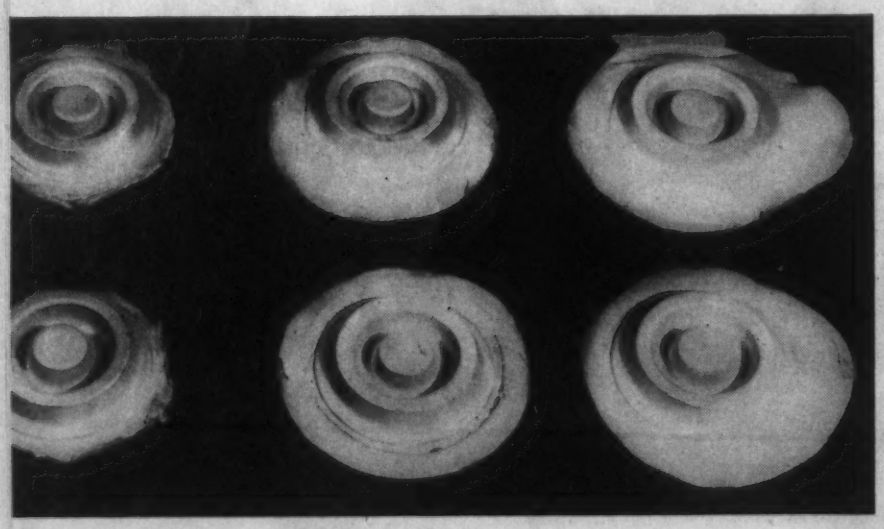


Fig. 5. Piston forgings, upset, blocked and finished in the press.

represented by the AM3S, and with AM57S and AM58S representing the other two classes, are shown in Figs. 3, 4, and 5. The small circular forging shown in the photographs was made in the three type alloys from each of two size multiples: one 2½ in. in diameter and the other 3¼ in. in diameter. The production cycle consisted of three operations: Upsetting to the diameter of the piston forging, blocking with wide radii on all corners and edges, and finishing. In this series of experiments, three definite procedures were employed.

1. All three operations in the hammer.
2. Upset and block in the press and finish in the hammer.
3. Upset, block and finish in the press.

Under the first procedure the AM3S and AM57S alloys made satisfactory forgings from both size multiples, while the AM58S alloy could not be flattened and blocked without shattering. A satisfactory forging was made, however, in AM58S alloy from the 3¼ in. multiple.

When the 2½ in. multiples were upset and blocked in the press, and then finished in the hammer, a 100% yield of satisfactory forgings was obtained. Similarly, a 100% yield was obtained by completing the forging operations in the press.

It will be noted in the photographs of the forgings that the flash on the AM57S and AM58S alloys, finished in the hammer, cracked very badly and disintegrated in at least the finish blow. This makes hammer operations on the high strength alloys hazardous unless the proper precautions are taken to prevent the flying of the hot, sharp particles. Where low strengths are permissible, one of the hammer forging alloys can be employed with greater safety, since the flash has very little tendency to shatter in the hammer operation.

It might appear from the foregoing that the high strength alloys should be forged in the press only, and that hammer operations should be avoided. However, this brings up other problems in the production of certain types of forgings, particularly when high thin ribs must be raised. It has been reported that the press capacity required for such forgings in the finish operation is about 50,000 p.s.i., which sets a requirement of very large equipment to handle intermediately large jobs. On the other hand, where a hammer operation can be used to raise the same ribs or corners, a relatively small unit at considerably less overhead may be employed. Therefore, it appears that the press and hammer combination can be used to advantage.

Forgeability

Because of the unique crystallographic structure of magnesium alloys, certain of the conventional forging operations cannot be performed, or must be performed, if at all, under carefully controlled conditions. When the magnesium alloys are extruded, the crystals become oriented with respect to the axis of extrusion, the basal planes becoming perpendicular to the axis. The slip planes are, therefore, oriented perpendicular to the desired direction of deformation during any process requiring elongation along the original axis.

Two operations of fundamentally the same nature which are widely used in making certain types of aluminum and steel forgings having long sections of varying area, are rolling and fullering on flat or concave-convex dies. These operations consist in elongating certain sections of the extruded bar and frequently accomplish the gathering of metal in some other area when a larger cross section is required. In operation the bar is first struck on one side, then turned 90 deg. and struck a similar blow. This procedure is continued until the desired reduction in area is accomplished.

Table I.—Nominal Chemical Compositions of Standard Magnesium Forging Alloys

Designation*				Nominal Chemical Composition					
Amer. Mag.	*Dow*	*ASTM*	*AMS*	*Al*	*Zn*	*Sn*	*Si (max.)*	*Mn (min.)*	*Other impurities (max.)*
AM3S	M-1	11	—	—	—	—	0.3	1.2	0.3
AM3	M	—	—	—	—	—	0.3	1.2	0.3
AM52S	FS-1	18X	—	2.5-3.5	1.3 (max.)	—	0.3	0.1	0.3
AM52	FS	18	—	2.5-3.5	1.3 (max.)	—	0.3	0.1	0.3
AM57S	J-1	8X	4350A	5.8-7.2	0.4-1.5	—	0.3	0.15	0.3
AM57	J	8	—	5.8-7.2	0.4-1.5	—	0.3	0.15	0.3
AM58S	O-1	9X	4360	7.8-9.2	0.8 (max.)	—	0.3	0.15	0.3
AM58	O	9	—	7.8-9.2	0.8 (max.)	—	0.3	0.15	0.3
AM65S	D-1	—	—	3.0-4.0	—	4.0-6.0	0.3	0.4	0.3
AM65	D	—	—	3.0-4.0	—	4.0-6.0	0.3	0.4	0.3

* The first designation is for the high purity alloy, while the second is for lower purity alloy of the same nominal composition.

Table II.—Specified and Typical Properties of Magnesium Forging Alloys

Designation	*Tensile Properties*						*Elongation (%)*			*Compression Yld.*		*Brinell Hardness*	
	Tensile Strength (Psi.)			*Yld. (0.2% Offset) (Psi.)*									
Amer. Mag.	*W-G*[3]	*Typical*	*Spec'd Min.*	*W-G*[2]	*Typical*	*Spec'd Min.*	*W-G*[2]	*Typical*	*Spec'd Min.*	*W-G*[2]	*Typical*	*W-G*	*Typical*
AM3S	37,000 41,000	36,000	29,000	27,000 37,000	26,000	12,000	2 10	7	2				47
AM52S	38,000 41,000	39,000[1]	35,000[1]	26,000 33,000	28,000[2]	22,000[1]	10 15	15[1]	11[1]	11,000 17,000		59 67	50[1]
AM57S	43,000 54,000	42,000	38,000	29,000 44,000	27,000	22,000	9 14	12	6	12,000 22,000	18,000	59 82	57
AM58S	43,000 57,000	46,000	42,000	30,000 46,000	32,000	24,000	6 13	10	5	12,000 27,000	22,000	69 96	65
Aged[3]	45,000 55,000	48,000	42,000	38,000 45,000	34,000	28,000	4 2	6	2	28,000 33,000	26,000	80 96	72
Q+A[3]	47,000 52,000	50,000	—	35,000 39,000	34,000	—	5 12	6	—	16,000 23,000	24,000	76 88	72
AM65S	39,000 43,000	38,000	35,000	34,000 36,000	22,000	20,000	5 7	12	6				52

[1] *Extrusions. No data on forgings are available.*

[2] *Upper figure is the minimum value obtained in a representative forging in the present project and the lower figure is a maximum.*

[3] *The solution treatment was 2 hrs. at 700 F followed by water quenching. Age treatment was 16 hrs. at 325 F.*

The results of attempted rolling of 1¾-in. stock of the various forging alloys are shown in Figs. 6 and 7. The first evidence of failure was in transverse, internal rupturing in two planes, approximately 90 deg. apart. Further reduction by rolling produced longitudinal failures on the rolled surfaces. The hammer forging alloys AM3, AM52, and AM65 were reduced to a slight extent before rupturing occurred, while the higher strength AM57 and AM58 alloys failed on almost the first blow.

No further rolling tests have been attempted, but it appears that unless the metal can be fully enclosed during the hammer operation, any further attempt would meet with failure.

Influence of Re-heating

In production, many forgings require multiple operations, which necessitate cooling the metal after the first operation and then reheating for the subsequent steps. This procedure can be used in aluminum and steel forgings, but has not been as successful to date in the manufacture of magnesium forgings. Fig. 8 demonstrates the result of forging in one heat as

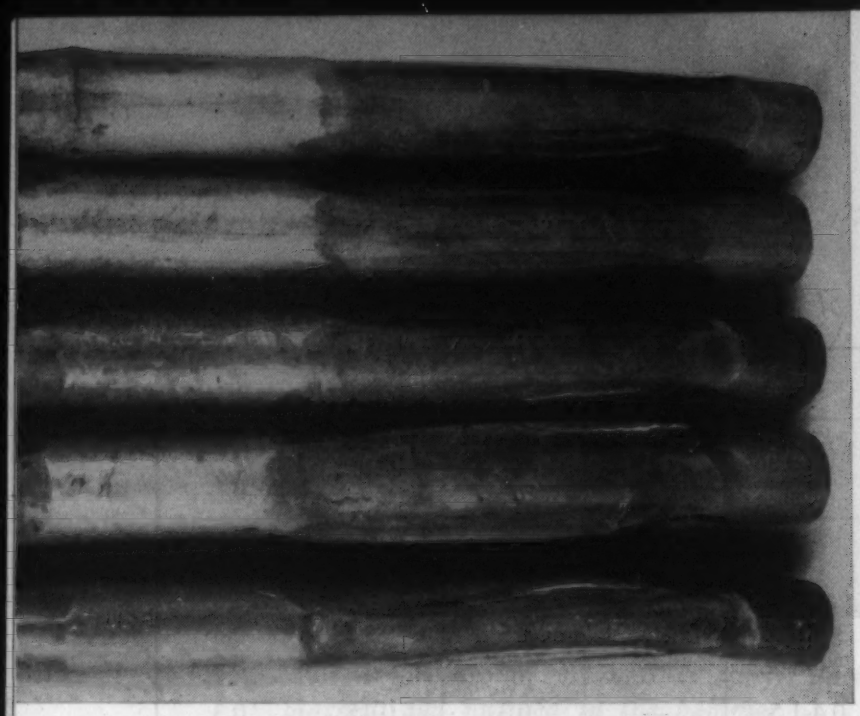


Fig. 6. Magnesium alloys as "rolled" in the hammer.

compared with re-heating between the blocking and finishing operations. The middle forging is a multiple after blocking in the press, while the two end forgings were completed in the hammer from similar blocked multiples. The forging on the left was completed in one heat with blocking dies at 600 F and finish dies in the hammer at 400 F. The right forging was handled similarly, but after blocking was re-heated for 1½ hr., then finished.

It will be noted that the re-heated forging cracked badly transversely to the original grain flow in the forging stock, while the forging finished in one heat was entirely sound. This type of behavior has been encountered many times during the research work on magnesium forging alloys, particularly in the AM58S alloy.

Another example of the transverse failure encountered in re-heated forgings is shown in Fig. 9. This forging is made from a 4-in. diam. multiple which is upset during blocking to a dish shape disc approximately the same diameter as the finish forging. During the finish operation the corners are raised and the multiple is sized. As indicated in the photograph, the forging made by re-heating after blocking cracked radially while the forging completed in one heat was entirely sound.

These and other experiments demonstrate, therefore, that it is desirable to complete the forging operations on a multiple in one heat. If this cannot be done, it is desirable that the first operation after the re-heat be performed at a relatively slow rate of work.

Influence of Die Temperature

As discussed before, it is essential that magnesium alloys be forged at temperatures in excess of about 500 F in order that sufficient ductility to permit metal flow may be achieved. This requires that the dies be maintained at some elevated temperature in order that the heat extracted from the multiple by the dies will not be sufficient to cool the multiple to below 500 deg.

Another factor that should be considered, however, is that by a careful balance at die temperature, forging temperature, and rate of working, the metal may be cooled in the final stages of forging to a relatively low temperature and finished at a temperature which results in a slight degree of work hardening. If carefully adjusted, this produces forgings with somewhat superior properties as compared with others made in dies maintained at somewhere near forging temperature.

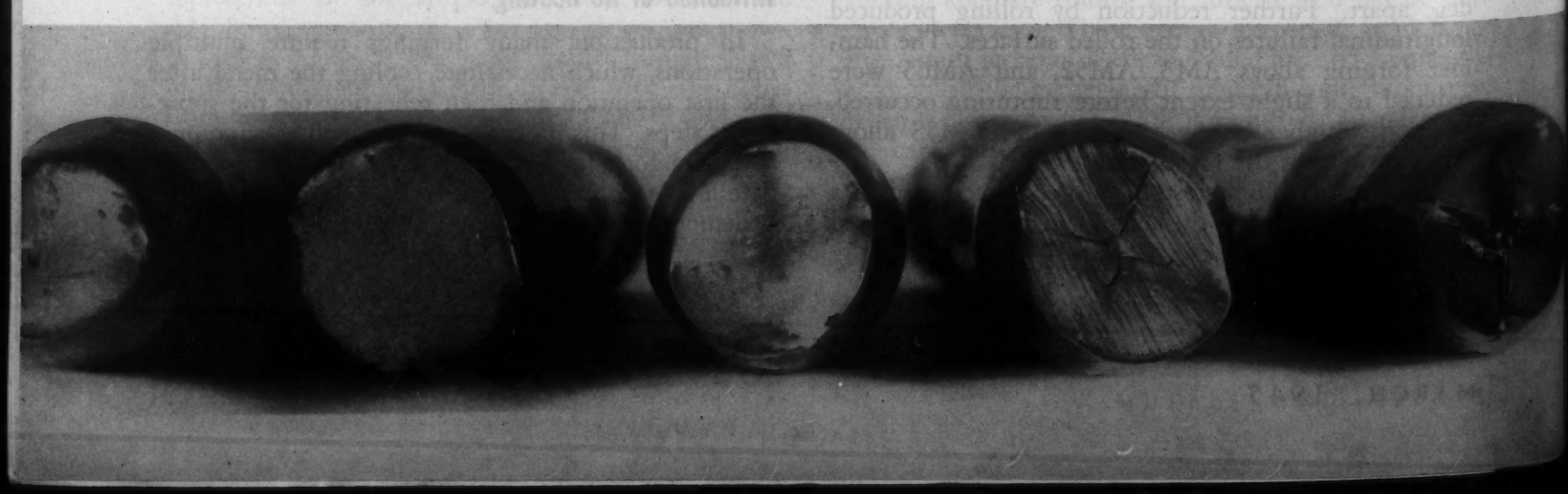
No comprehensive investigation of this factor has been completed. Indications to date are, however, that the finishing dies should be maintained at about 400 F in a hammer finishing operation. Table III presents the result of tensile tests on forgings made in dies held at 600, 400, and 200 F respectively. The properties of the forgings made in the dies at 200 F were superior to those made in the hotter dies. However, fracture tests and grain flow etches indicated that the thin sections in the forging made in the 200 deg. die have been chilled excessively before the forging operation was completed and had cracked. The grain flow in question is shown in Fig. 10. The section at which the cracks occur is about 3/16 in. thick on the finish forging. Fig. 11 shows a grain flow on a similar forging finished in dies at 400 F. This forging was entirely sound, and it appears that for this particular job, a die temperature of about 400 deg. would be more desirable.

Heat Treatment

In Table III it is shown that as the temperature in the finish die is decreased, the tensile properties of the finished forging are increased due to the work hardening effects in the finish die. Since the high strength alloys, AM58 and AM57, contain an appreciable quantity of aluminum, which has a variable solubility with varying temperature, it is possible to improve the tensile properties further by age hardening.

In the forgings made to date, a number of heat-treating procedures have been employed, including direct ageing after forging, water quenching from the die plus ageing, or quenching and ageing after air cooling from the die. Variable times and temperatures for the solution treatment or ageing treatments have been employed. However, the most successful treatments are those tabulated in Table III. Where the maximum room temperature properties are de-

Fig. 7. End view of magnesium multiples as rolled in the hammer.



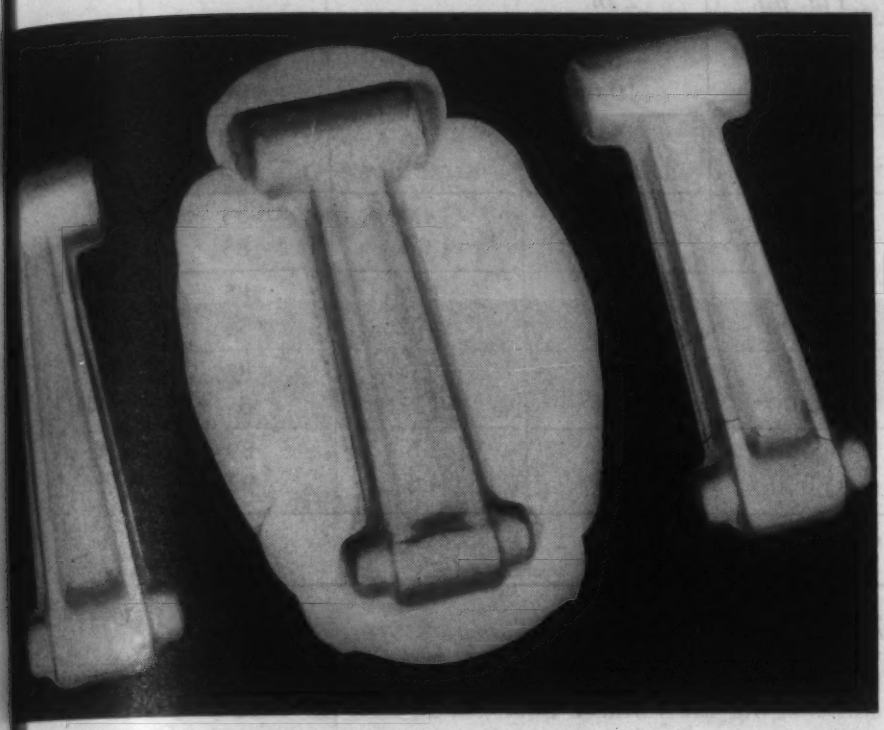


Fig. 8. Magnesium alloy forgings of alloy AM58S, finished in one and two heats, respectively. The forging at the left was made in one heat; the center one is the result of blocking; and the one at the right has been reheated after blocking.

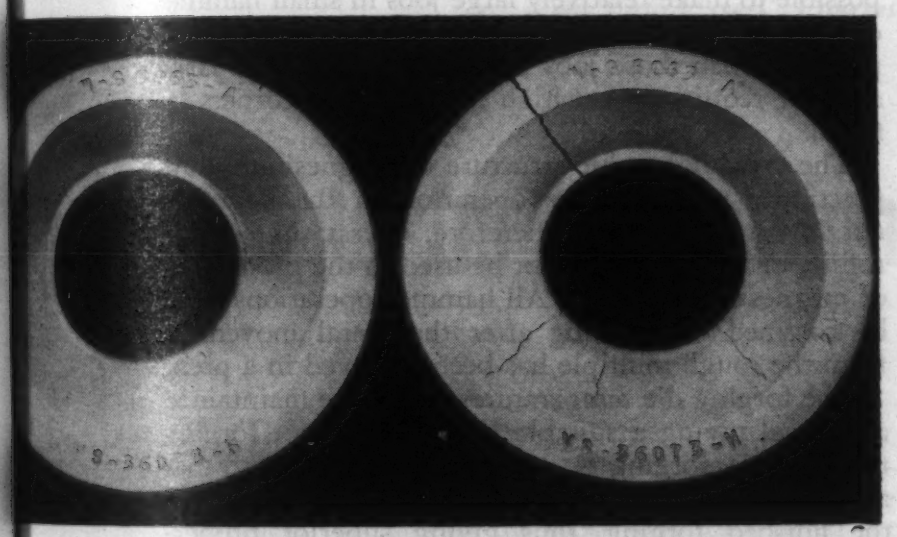


Fig. 9. Alloy forgings of alloy AM58S, finished in one and two heats respectively. The one at the left was made in one heat, and the other was reheated after blocking.

sired, an ageing treatment of about 16 hr. at 325 F preceded by a direct quench from the hammer or press produces the maximum strength in the AM58S alloy. For high temperature applications in which a coarse grain is more desirable, a quench and age treatment may be used. Adequate solution with a minimum, although appreciable, grain growth is achieved in 2 hr. at 700 F. After solution treatment, the alloys can be aged for 16 hr. at 325 F.

As indicated in Table III, the ductility of the AM57S and AM58S alloys was decreased from that as-forged by subjecting the forgings to an ageing

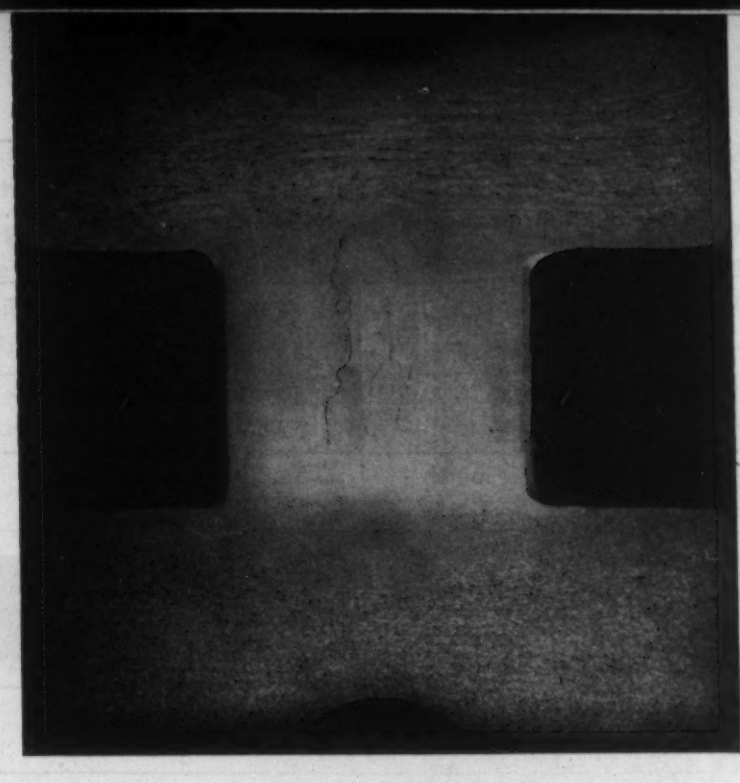


Fig. 10. Grain flow of AM58S alloy forging, finished in dies at 200 F.

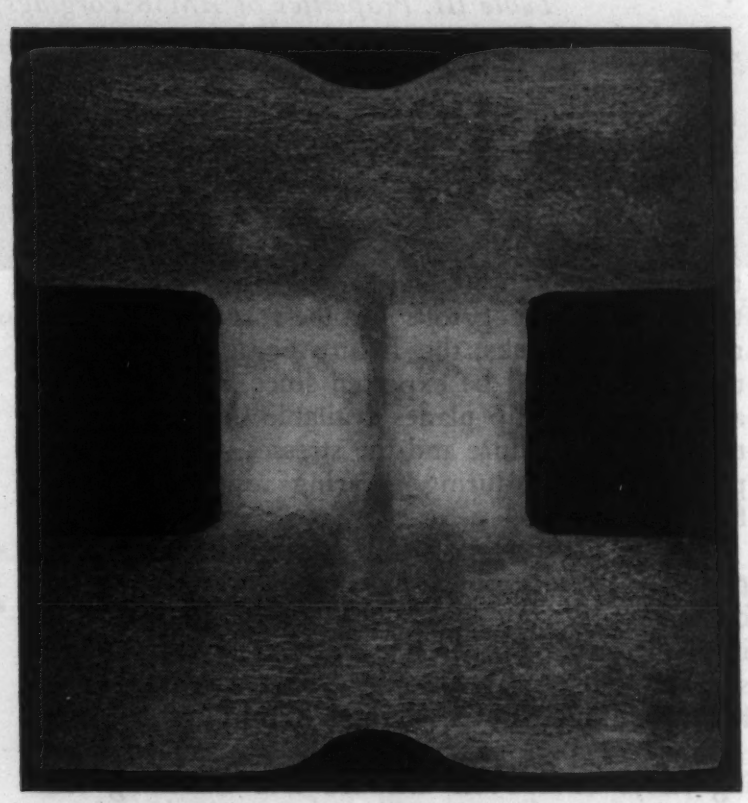


Fig. 11. Grain flow of AM58S alloy forging finished in dies at 400 F.

treatment at 325 F. Still further decreases in ductility were achieved by the solution treatment and ageing procedure; however, since the specified minimum for the aged AM58S alloy is only 2% elongation in 2 in., no particular difficulty is encountered in meeting this specification.

Influence of Trimming Temperature

One of the difficulties encountered in the production of magnesium forgings is in obtaining a clean trim, free from tearing and smearing. The crystallographic structure is oriented during the flashing of the forging, such that the basal plane of the hexagonal lattice lies normal to the sides of the forging. Therefore, a trimming die must shear the flash along the basal plane.

Die Temperature (deg. F.)	Heat Treatment*	Tensile Properties					
		Ultimate (psi.)	0.1% Offset Yld. psi.	0.2% Offset Yld. psi.	Elong., % in 2 in.	Red. of Area (%)	Brinell Hardness
200	none	53,900	42,000	48,800	6.5	10.6	88
		55,400	42,500	44,400	10.0	16.5	90
	Q + Age	49,900	37,500	39,100	5.0	6.5	80
		57,550	36,500	38,900	7.0	6.1	86
400	none	54,500	40,000	41,000	10.0	14.0	83
		54,100	38,000	40,200	11.0	13.6	83
	Q + Age	52,000	34,200	37,000	7.0	6.1	85
		48,000	33,600	37,000	3.5	4.2	83
600	none	51,300	36,700	38,750	10.0	19.8	83
		52,000	36,000	38,600	13.0	12.8	84
	Age	55,400	42,500	44,500	3.5	2.6	89
		53,800	43,000	45,000	4.0	4.6	92

*Q + Age = Water quenched after 2 hrs. at 700 F and aged 16 hrs. at 325 F.
Age = 16 hrs. at 325 F.

Table III. Properties of AM58 Forgings Forged in Dies at Varying Temperatures.

Experiments have been conducted to determine the most favorable trimming temperature on a number of jobs. Forgings have been completed, then re-heated to temperatures varying from room temperature to 700 F, soaked, then trimmed in a punch-out press. Fig. 12 shows three pairs of AM58S alloy forgings trimmed at 200, 450, and 700 F respectively. Those trimmed at 200 deg. tore into the forging and opened rather large cracks, the failure being of the brittle type. This would be expected since, at that temperature, the only slip planes available lie perpendicular to the line of failure and the stresses normal to these planes imposed during shearing resulted in actual failure.

Forgings trimmed at 450 F were free of trimmer tears and were entirely acceptable on a commercial basis. Those trimmed at 700 F smeared very badly in the trimming operation and could not be considered commercial forgings. This was due to the high ductility achieved at the trimming temperature.

In each experiment, each of the five standard forging alloys have been included and trimming temperature ranges have been determined. The trimming temperature range for the AM3 alloy is about 300 to 450 F, while for the AM58 alloy the range was 350 to 500 F. The other three alloys had intermediate trimming temperature ranges.

Summary and Conclusions

Forging runs that include all the standard American forging alloys have been made and procedures by which each can be worked successfully have been developed. The three lower strength alloys AM3S, AM52S, and AM65S can be handled in the hammers, while AM57S and AM58S must be handled by a modified procedure; either completely forged in the press, or blocked in the press and finished in the hammer. The latter procedure offers some promise, since it is possible to make relatively large jobs in small hammer equipment, whereas it would require a large hydraulic press to finish those jobs having intermediately large areas or requiring that high ribs or sharp corners be filled.

The crystallographic structure of magnesium alloys practically prohibits any operation in the hammers not in confining dies. Therefore, operations such as rolling or fullering may not be used in the production of magnesium forgings. All hammer operations must be confined to finishing after the metal movement from the rough multiple has been achieved in a press.

The forging die temperatures should be maintained at a level giving a suitable balance between forging temperature, forging rate and die temperature so that a certain amount of cold work may be introduced into the finished forging, thus giving superior properties. Still further improvement in properties can be achieved by ageing. The solution treating and ageing treatment are recommended for only high temperature applications which require a relatively coarse grain. Otherwise, it appears that the ageing treatment only should be used.

Fig. 12. Forgings of alloy AM58S trimmed at the temperatures indicated.

A Materials Symposium The relative merits of low alloy steels, stainless steels, and aluminum and magnesium alloys as materials of construction are being pondered by engineers now planning the design of railway cars, aircraft, buses, trucks—indeed, anything that moves or must be carried—to decrease their dead-weight and thereby increase speed, payload, operating economy or convenience, without sacrifice of safety. A basis for comparison is provided in the three articles presented here, which give the pertinent properties, design advantages and limitations, and general possibilities for each type of material in lightweight construction. The data have been assembled from the papers in two recent symposia on this general subject (one by the New Jersey Chapter of the American Society for Metals and the other by the New York Engineering Societies' Committee on War Production) that one of your editors helped to organize. The contributing authors are indicated above each article.

This gasoline trailer truck tank body, made of a low-alloy high-strength steel, weighs 750 lbs. less than if made of plain carbon steel. Courtesy: Youngstown Sheet & Tube Co.

Metals for Lightweight Construction—A Symposium

Introduction

The possibilities inherent in the "lightweight development" are among the most significant of all the future engineering trends visible today. From time immemorial design engineers have concentrated their attention on bulking-up the mass of material in their structures, the basic procedure being to determine the loads and stresses involved and then to provide more (often much more) than enough metal to carry them safely.

The modern era has brought bigger and bigger structures and increasingly emphasizes speed in everything that moves, and the more progressive engineers have therefore carefully studied their actual service loads and their materials and obtained the most specific and accurate data possible on both so that "factors of safety" and therefore excess weight could be reduced. But the greatest strides in weight-reduction have been made through the use either of strong *lightweight* materials or of *high-strength* alloys, and it is to this trend that manufacturers and users of all types of transportation equipment look as the basis for the great improvements in speed, convenience and economy that are certain to be forthcoming.

Similarly, products or component parts that must be lifted, from aircraft and mine-skips down to vacuum cleaners and cooking utensils, and structures (like bridge decks or building units) that must be supported by other members, will be lighter because of this development.

At the moment the lightweight development is in a state of flux. The transportation industries and their design engineers recognize that less weight can mean either higher speed, less power consumption or greater pay-load for commercial carriers. But there is no agreement (nor is a universal solution logically to be expected) as to the best material to accomplish weight-reduction in design generally. Both the lightweight materials (aluminum alloys, magnesium alloys, plywood, etc.) and the high-strength materials (low-alloy steels, stainless steels, heat-treated steels, etc.) are being investigated for all types of moving products or parts. The railroad industry, for example, appears to like low-alloy steels, stainless steels and aluminum alloys in about that order for its lightweight passenger cars (of which thousands will be made when the war is over), but the subject is currently receiving widespread study and the final lineup may be quite different.

The three groups of materials receiving the most consideration by designers of lightweight structures

are individually described, together with their advantages and limitations for such construction, in the following three articles. This introductory article is intended merely to give a bird's-eye-view of the whole picture, and includes a table in which have been assembled for convenient comparison the significant engineering properties of all these materials.

At best, comparisons like this can be no more than screening operations, since so many different factors are involved in the various applications. For example, the initial material-cost of a structure may at first seem important, but actually it may have only a slight proportionate effect on the total cost, and the more expensive structure to produce may even turn out to be the most economical as a long-term operating unit.

The war has had the most pronounced effect on aluminum and magnesium by enormously increasing their production capacities and by spreading knowledge of their fabricating behavior on a much broader scale. For extreme light weight and highest speed, the light metals are usually the most popular. Stainless steels, on the other hand, have great eye-appeal, with outstanding strength-weight ratios in the cold-rolled condition. Furthermore, they require no painting or other protection. The low-alloy steels, finally, have good all-round (and fabricating) properties, are the cheapest of this group and can be used as-rolled—that is they do not require heat treatment as do the aluminum alloys nor must they be fabricated in the cold-worked condition as must the stainless steels.

So look them over and take your choice! In the end the happy solution to many lightweight-design problems will be combinations of more than one material in the same structure, using simultaneously the best properties of each where they will do the most good.

—F. P. P.

Low-Alloy High-Strength Steels

from papers by **Frederick D. Foote**
Alloys Development Corp., New York

The low-alloy high-strength steels were developed to fill a need in the transportation field for properties in steel superior to those possessed by the conventional structural grades commonly used. Some years ago a survey of leading engineers in that field disclosed a growing consciousness of excessive deadweight in their equipment. Asked what they required to provide lighter and more efficient designs that sacrificed nothing in maintenance costs, service life or safety, they came up with virtually identical answers.

In the first place, they wanted greater strength to permit a substantial increase in unit stresses, and thereby make possible a proportionate decrease in section modulus. Since this led to lighter gages, they next demanded increased corrosion resistance to offset the reduction in initial thickness. Then they wanted a composition that could be formed easily, hot or cold, and which could be readily welded without heat treatment and generally without subsequent annealing or stress relieving. Also, these properties should be provided in the as-rolled condition, because large structures like freight cars, barges, mine cars, etc. cannot be easily heat-treated after fabrication. Finally, all these properties should be available in a steel of relatively low cost.

This appeared to be a large order, but out of it came the low-alloy, high-strength steels, the properties of which nicely match the requirements posed by those engineers. The term "low-alloy high-strength" steel is meant to include steels to which moderate amounts of alloying elements have been added, imparting in the as-hot-rolled condition a yield strength of 50,000 p.s.i. minimum, in sections of ½ in. and lighter, and which experience indicates will result in atmospheric corrosion resistance 4 to 6 times that of mild carbon steel.

Design-Properties

Ordinary structural steel has held a prominent place in the construction industries and consequently forms a basis for evaluating the low-alloy steels and their performance. The minimum yield strength of structural steel is 33,000 p.s.i.; that of the typical low-alloy high-strength steels 50,000 p.s.i. The minimum tensile strength of the former is 60,000 p.s.i., compared with 70,000 for the latter. The minimum elongation of both in 2 in. is 22%.

From an engineering standpoint, the most significant physical property of the low-alloy high-strength steels is their high yield strengths. This property owes its importance to the general design practice of basing unit working stresses upon yield point, the point beyond which permanent deformation occurs. Comparing the two types of steel, the working unit stress in tension for the low-alloy steel will be in the ratio of their yield points, giving us a figure 1½ times that of ordinary structural steel.

Weight saving is the prime benefit conferred by these stronger steels. On the basis of the permissible 50% increase in unit stresses, a saving of 33⅓% is obtained in tension members; 29% in typical compression members, and about 25% for rolled beams and channels which have been designed for section modulus. Experience with a wide variety of applications has demonstrated that with all factors considered, weight saved averages about 25%. Under the most favorable conditions, skillful designing may increase this saving to approximate that of tension members—namely, 33⅓%.

The reduction in thickness which results from the use of low-alloy steels may often raise problems of elastic stability. The aircraft industry has devoted itself to the weight saving possibilities of this problem, but much remains to be done. It is a field little explored so far in the design of many structures, and often only tests of the actual structure or of its members will provide the desired knowledge.

The modulus of elasticity is the same for both ordinary and high-strength steels; hence, the deflection of a structure employing the latter will be somewhat increased, due to the higher working unit stresses, but in the majority of cases this increase will be of slight proportions. Deflection becomes a serious design problem, however, when either aluminum or magnesium is employed, since the modulus of elasticity of the former is but one-third that of steel, and of the latter less than one-fourth.

Reduction in thickness of material also raises the question of corrosion. Experience, and an exhaustive amount of testing, have demonstrated that the superior corrosion resistance of these steels is due to the more dense, tightly adherent, and (presumably) impervious rust coat which forms on their surfaces. A period of at least two years (preferably five) is required to obtain a trend in the atmospheric corrosion behavior of such compositions. Only a steel which provides the type of protective film described above, at a minimum cost in terms of the elements employed, will serve the economic objectives desired. Where the selection of the composition has been made so that a minimum loss will result, further alloy additions will neither substantially nor economically improve the atmospheric corrosion resistance of this type of steel. Strength requirements and other considerations indicate that an atmospheric corrosion resistance of four to six times plain carbon steel is essential, and this is the degree which is used as the basis for weight reduction in this discussion.

Corrosive conditions are variable throughout the applications of steel. For example, they are much more severe in open-top railroad equipment than in box cars or covered hopper cars. Where atmospheric corrosion predominates in the conditions of service, and this is the case with a large majority of all transportation equipment, a comparison of the corrosion data obtained through exposure tests over a period of many years, for structural steel and steel containing 0.20% copper, is most useful. On this basis, a superiority in atmospheric corrosion resistance of two to three times that of ordinary steel indicated that copper-bearing steel would give a service life 1½ times that of ordinary steel. Typical low-alloy high-strength steels provide an atmospheric corrosion resistance two to three times that of copper-bearing steel.

Thus, these superior steels give a service life 2¼ times plain steel and 1½ times copper steel. During the past ten years, the service performance of many structures built of one of the low-alloy steels has justified the early conclusions reached through comparisons of data obtained in earlier atmospheric corrosion tests.

The degree of corrosion resistance discussed is important. Any ratio less than that given for low-alloy steel, over copper-bearing and plain steel, would raise the required thickness and thus also the weight.

Fatigue and impact properties are important, too. The fatigue value of high-strength steels averages about 45,000 p.s.i., compared with 26,000 for ordinary steel. In many cases fatigue failure arises from notches, scratches, tool marks, discontinuity in the metal, or abrupt changes in cross section, all of which give rise to the phenomena known as "stress concentration." Action of this kind is not due so much to the steel itself as to the geometry of the member. Impact strength at low temperatures is also a frequently-met requirement. The answer in the case of these steels is supplied by the thousands of structures built of both ordinary and low-alloy steel that have performed satisfactorily under rigorous operating conditions at very low winter temperatures.

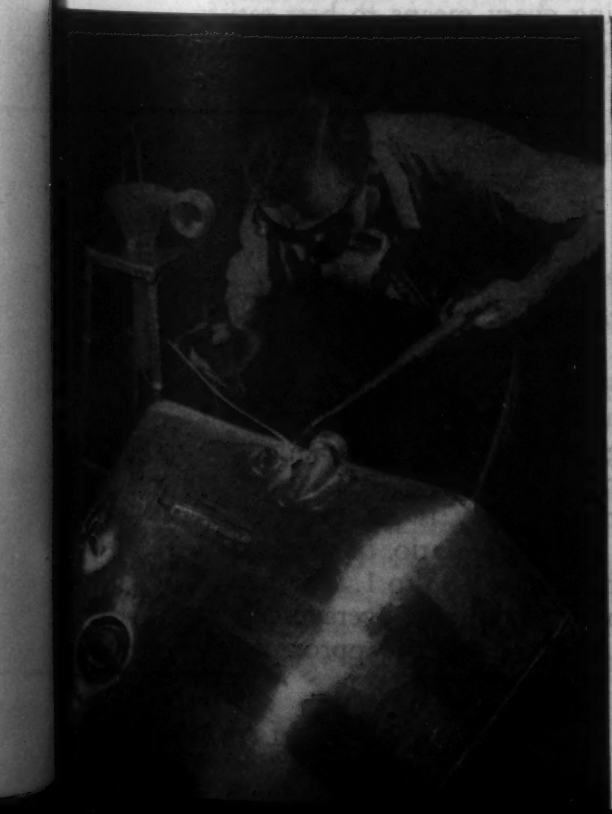
No design can be considered adequate if it has not taken into account the performance of the steel as it goes through the forming and fabricating processes. Here ductility plays an important part. Higher yield point requires greater effort or force to deform the steel beyond the elastic range, as in pressing or bending. This extra effort is offset in large measure by the thinner sections used in low-alloy high-strength steel designs.

One important fabricating process—namely, welding—has raised many questions. Designing for welded construction is quite different from the procedure in riveted construction. The most satisfactory welded structures are those in which this difference is recognized and a real attempt is made to adapt the design to the characteristics of welding. The high-strength steels achieve their superiority by the addition of alloying elements, the effect of which is to alter the behavior in welded structures. Welding is extensively used for their fabrication, and the resulting structures (particularly railroad cars) are performing in a creditable manner.

Although the initial cost per pound of the low-alloy high-strength steels is about 50% greater than that of plain carbon steel, by skillful design and the use of proper fabricating methods, the cost of the finished structure is, in many instances, little, if any, more. In some cases the cost is even less in terms of the added capacity provided.

Applications

Now for a few examples of weight-saving in different structures designed to use low-alloy steels.



Torch welding a magnesium alloy airplane oil tank.

Mechanical Properties of Some Common Materials used for Lightweight Construction. The values given are typical rather than average.

Material and Form	Specific Gravity	Weight, lbs. per cu. in.	Tensile Strength, p.s.i.	Yield Strength, p.s.i.	Elong., % in 2 in.	Modulus of Elasticity, million p.s.i.	Fatigue Strength, p.s.i.
Ordinary Structural Steel, 0.20% C, open-hearth, hot-rolled	7.86	0.284	60,000	35,000	28	30.0	30,000
Low-Alloy High-Strength Steel (Cor-Ten), hot-rolled	7.87	0.284	70,000	55,000	20	29.0	45,000
Stainless Steel, 17-7 (type 301), cold-rolled	7.9	0.285	196,000	164,000	15	26.0	80,000
Aluminum Alloy, 75 ST, extruded, aged	2.8	0.1	88,000	80,000	10	10.4	22,500
Aluminum Alloy, 24 ST, plate, aged	2.77	0.1	68,000	44,000	19	10.3	16,000
Magnesium Alloy, O-1 or 58 S (as extruded)	1.81	0.065	49,000	33,000	11	6.5	19,000
Impregnated Plywood	1.30	0.046	30,000	—	—	3.7	—

A standard A.A.R. box car in carbon steel weighs about 45,000 lbs. Box cars of the same inside dimensions and identical equipment, built of all-welded low-alloy high-strength steel, weigh about 36,000 lbs. —a saving of 4½ tons per car.

A standard A.A.R. hopper car on 50-ton trucks in ordinary steel weighs about 42,000 lbs. Modern lightweight hopper cars providing increased pay load capacity, equal to the amount of weight saved, can be built to weigh 32,000 to 33,000 lbs., using standard A.A.R. specialties. These cars would have a life expectancy equal to or longer than that of the heavier designs built of ordinary steel. In 1935, 115 extremely light hopper cars were built on 50-ton trucks which weighed only 30,500 lbs. All of them were placed in operation late in that year on four different railroads, and are completing ten years of service.

The side and end sheets of the cars, and also the upper slope floor sheets, were 3/32 in. thick, as compared with a normal thickness of 3/16 in. carbon steel. The lower slope floor sheets were ⅛ in. thick and the hopper sheets 5/32 in., as compared with normal thicknesses in carbon steel of ¼ in. and 5/16 in. One hundred of these cars have been used in coal and ore service requiring them to pass through car dumpers at the end of each trip. An inspection report at the end of nine years of service gave no indication of a time when the cars would need to be shopped for heavy repairs! These cars were designed with a capacity to carry six additional tons of coal, when compared with conventional carbon steel cars of standard A.A.R. design.

The weight of a main line passenger coach was formerly about 80 tons. Cars built in the past ten years of low-alloy high-strength steel and all-welded design, and with the same seating capacity, average about 55 tons—a saving of 25 tons per car, including the extra weight of air conditioning. This saving in weight is accomplished at no sacrifice in car life or safety. In fact, due to design improvements, all-welded construction, and the use of high-strength steel, the new cars have an increased safety factor over the older and heavier ones. This increased safety has been measured by tests and also by the behavior of the cars themselves in road accidents.

Modern Pullman cars have employed low-alloy high-strength steel in their outside sheathing and stress-carrying members. Their smooth appearance is due to their all-welded construction. Because of their lighter weight, longer trains can be carried with the same motive power.

It is interesting to note how weight saving spirals in these new passenger car designs. Because of the substantial reduction made in body weight, it is possible to employ 4-wheel trucks in place of the 6-wheel trucks previously required to operate the older and heavier cars. This eliminates one-third of the wheels employed per car, and contributes handsomely to the overall reduction in weight. In general, the re-design of all types of structures for the use of high-strength materials results in such multiplications of weight saving from top to bottom.

Some structures to which low-alloy high-strength steels have been applied, other than in railroad cars, are as follows:

The capacity of a mine skip was increased from 7½ to 10 tons of coal without increasing the load on the hoisting equipment. Fifteen Tainter gates each 75 ft. in length (longer than any similar gates previously constructed) were used in a dam in the Mississippi River. These lighter gates made possible a substantial decrease in the weight of the lifting chains, operating machinery, and supporting structures.

On an all-welded barge ¼ in. high-strength steel side and bottom plates were substituted for the 5/16 in. thickness formerly used, and 3/16 in. bulkhead plates for ¼ in. These reductions afforded an increased load capacity. A derrick mounted on the deck of this barge had a 40 ft. boom of high-strength steel which was lighter than the wood boom previously used.

High-strength steel was used in the design of a number of highway trailers constructed for the transportation of automobiles. A weight saving of 1,200 lbs. per unit was achieved, effecting substantial reductions in operating costs.

A substantial increase was needed in a side wall coal loading machine located at Hampton Roads, Virginia. The piling under the pier was already loaded to capacity. The necessary weight saving was accomplished through the use of low-alloy high-strength steels, thus avoiding a costly reconstruction of the pier itself.

Many other interesting examples could be cited, but those referred to should suffice to indicate the potentialities of this new development. The world is becoming "lightweight-minded" very rapidly. The trend was clear long before the war, and is now unmistakable. Maneuverability and speed, coupled with a high degree of stamina, are qualities demanded in structures for mechanized warfare. War demands and the necessity of utilizing every means to best satisfy them have been a powerful challenge to the ingenuity of engineers and metallurgists everywhere, and the success with which they are meeting the challenge promises many innovations when peace comes.

Stainless Steels

from papers by **Stanley P. Watkins** *Rustless Iron and Steel Corp., Baltimore, Md.*
and **Russell Franks** *Union Carbide and Carbon Research Labs., Inc., Niagara Falls, N. Y.*

It is generally conceded that in lightweight construction, especially in aircraft, there must be a compromise in design and material. An all-wool, or an all-aluminum, or an all stainless steel aircraft, for example, cannot be as efficient as one in which each of the component parts has been fabricated of that particular material best adapted to the individual requirements of structural strength, safety, aerodynamics, appearance, fabrication and costs.

Strength and Stiffness

In selecting material for lightweight construction, first consideration is generally given to the strength-weight ratio of the materials involved. The density of high strength aluminum alloy is 2.8 and that of stainless about 7.95. Thus the ratio of density of stainless to that of aluminum is 2.83 to 1. The tensile strength of high-strength aluminum averages about 62,000 p.s.i. with a yield strength of approximately

42,000 p.s.i. When it is taken into consideration that a given volume of stainless is 2.83 times as heavy as the same volume of aluminum alloy, it is evident that in order to have as good a strength-weight ratio, stainless must have a minimum yield strength of 120,000 p.s.i. and a tensile strength of at least 176,000 p.s.i. These properties in stainless are easily obtained in cold rolled austenitic stainless sheet and strip and in other forms in the heat treatable types of stainless.

The modulus of elasticity of high-strength aluminum alloy is about 10,300,000 p.s.i. and that of stainless approximately 27,000,000 p.s.i. Therefore, at comparable yield strength values, it is necessary for stainless to have no more than about ⅓ the cross-sectional area of aluminum alloy to compete on a strength-weight ratio basis.

In this connection it has been pointed out that rigidity of structure is as important as the strength-weight ratio and that although these requirements are met by using thinner gages of stronger stainless, the rigidity under compression requirements may not be satisfactorily met because this is not a function so much of strength as it is dependent on the ratio of length of the section to thickness of the section, or in other words, the slenderness ratio.

Thus, stainless will have less resistance to buckling than aluminum alloy where the cross-sectional areas are comparable from a strength-weight basis. This can be overcome by design, and resistance to buckling made to vary by corrugating, forming or design-reinforcing the section to impart greater stiffness.

There are two types of austenitic stainless steels that have been generally applied in lightweight structures, those containing approximately 17% chromium, 7% nickel and those containing 18% chromium, 8% nickel. The high strength of these steels cannot be obtained by the use of heat-treatment (as with aluminum alloy) but is secured by application of cold-work, as in the cold-rolling of sheet and strip, and the cold-drawing of bars, rods and wire. By controlling the percentage of cold reduction by rolling or drawing, it is possible to obtain high strength products of good ductility and toughness.

Thus a steel containing 17.20% Cr, 7.23 Ni and 0.11 C, annealed, has a tensile strength of 117,800 p.s.i., a yield strength of 33,000 p.s.i. and elongation of 68% in 2 in. Cold-rolled 35%, the same steel shows 196,000 p.s.i., tensile, 164,000 p.s.i. yield and 15% elongation, while an 18-8 steel reaches values almost as high (155,300 p.s.i., 131,000 p.s.i. and 15%, respectively) after the same cold-working.

Furthermore subjecting the cold-rolled strip to a low-temperature heat treatment at 390-525 F improves the yield strength without reducing the ductility; the 17-7 steel so treated will have a yield strength of 180,000 p.s.i. with 14% elongation and the 18-8 155,000 with 11%.

Fabricating Characteristics

This "cold-rolled" feature is the basis for one of the disadvantages of stainless steel for lightweight construction—the fact that its high tensile properties must be developed prior to fabrication by cold work, and consequently its forming is more difficult than is the case of some light metals, which can be formed in the soft condition and then heat-treated to develop their properties. However, experience has shown that with proper jigs and equipment, high-tensile stainless can be fabricated at surprisingly low cost.

These disadvantages of stainless for lightweight construction are far outweighed by the advantages, which include ease of welding, heat resistance, corrosion resistance, high elastic modulus, wide range of tensile properties, excellent low temperature properties, high fatigue strength, lower maintenance costs, high joint efficiency and ease of repairs.

The chromium-nickel stainless steels are among the easiest metals to resistance or spot weld. Their electrical resistance is 25 times that of aluminum and 8 times that of carbon steel. In keeping with its high electrical resistance, stainless has a low heat conductivity. Both these properties tend to aid spot welding; the former lessening the current required, the latter concentrating and conserving the fusion heat during welding. This enables stainless to be spot welded on low capacity machines.

Welding time is short, ranging from 2 cycles for thin sheet up to 20 cycles on thick sections. By proper spacing of welds, joint efficiency of 95% can be developed as compared to about 75-80% for a riveted joint. Spot welds do not add to weight, and can be made much faster than riveting, and consequently the cost of spot welding is considerably lower. Stainless steel is highly resistant to "notch effect" and spot welds on this material possess high fatigue resistance. Besides spot welding, stainless is seam welded, permitting the making of water-tight joints at low cost.

Service Behavior

One of the most important properties of the stainless steels is their relatively high fatigue strength in both the cold-rolled condition and after application of the low-temperature heat-treatment at 390-525 F. An 18-8 steel in the form of cold-rolled 0.035 in. strip has an endurance limit of about 60,000 p.s.i. (based on 20 million stress reversals), and, after heat treating, 65,000 p.s.i. Corresponding figures for a 17-7 steel are 72,000 and 76,000 p.s.i. High fatigue strength of the steels is important because of the thin sections involved in lightweight structures.

One of the major requirements of materials for lightweight structures is retention of toughness at subnormal temperatures, because thin sections of the materials are often employed, and many of the applications involve relatively low temperatures. Thin sections of both 18-8 and 17-7 can be bent through 180° at all temperatures down to -300 F without failure, showing that the metal is quite tough under these temperature conditions. Also, the steels exhibit high impact values under the same conditions, which shows that thick sections of the steels do not become brittle at the low temperatures.

A most essential characteristic of materials for lightweight construction is durability—i.e., relative freedom from wear under abrasion, and relative freedom from corrosive attack under atmospheric conditions. The surfaces of the cold-rolled stainless steels are comparatively hard and do not wear away rapidly when abraded with grit and dust particles that may come in contact with the metal during service. The tendency under such conditions is for the steel to work-harden and become more resistant to the abrasion.

The high inherent corrosion resistance of stainless steel to the atmosphere and sea spray eliminates the necessity for painting or otherwise protecting the surface as is necessary with the light metals and ordinary steel. This permits economy in design as well as reducing maintenance costs. Stainless steel structures, when correctly designed and properly used, require a

minimum of care with attendant low cost of maintenance. It is the most corrosion resistant of the commercial tonnage metals, but under some conditions will corrode and pit (as even the noble metals do). The surface of stainless steel should be kept clean as the accumulation of dirt, soot, cinders, iron particles and the like will generally result in localized discoloration, but rarely will it result in severe attack of the metal.

Spot and seam welds, if properly made, have as good corrosion resistance as the parent metal. Spot-welded stainless steel trains and smoke stacks on Navy destroyers after as much as 10 yr. service show no deterioration by corrosion.

Aluminum and Magnesium Alloys

from papers by **H. N. Hill** *Engineering Design Div., Aluminum Research Labs., Aluminum Co. of America, New Kensington, Pa.*

and **T. L. Fritzlen** *Reynolds Research, Reynolds Metals Co., Glen Cove, N. Y.*

Although aluminum and magnesium are playing a major role in the lightweight construction of war material, neither one can be regarded as superior to all other materials for lightweight construction. The fact that aircraft have been designed employing plywood, carbon steel and stainless steel as well as aluminum and magnesium alloys show this to be the case. Each material has its own characteristics which offer advantages or disadvantages, depending on use.

The most obvious means for obtaining lightweight construction is, of course, to use a lightweight material. Lightness alone, however, is not sufficient. The structure or part being designed must be capable of performing the service for which it is intended; that is, it must have sufficient strength. This double consideration of weight and strength leads directly to the much used and sometimes abused term "strength-weight ratio." Although this term contains two very important factors which must be considered in an analysis of lightweight construction, comparisons on the basis of so-called "strength-weight ratios" can lead to erroneous conclusions, particularly when comparisons are attempted for different materials.

A material does not have a "strength-weight ratio" for the simple reason that there is no single value that can adequately define the strength of the material for all the different types of loading to which it might be subjected. The tensile strength of a material might properly be considered the significant strength value in a simple tension member. For other kinds of members the strength may be controlled by the compressive, shear or fatigue properties of the material, or the design may be controlled by some buckling phenomenon, which involves a consideration of the modulus of elasticity.

Weight is frequently influenced by considerations other than strength. In some members a limited allowable deflection controls design. In other applications, dimensions are influenced by space limitations or dimensional limitations imposed by methods of fabrication. We can conclude, therefore, that the only reliable basis on which weight comparisons can be made is the weight of the completed structure.

The high strength-weight ratio of aluminum alloys and magnesium alloys of course, does permit their substitution for the heavier metals on a strictly tension basis with some increase in section to obtain a substantial weight saving. The modulus of elasticity of aluminum and magnesium alloys is approximately ⅓ and ¼ that of steel, respectively. The lower modulus of the light alloys offers an advantage in the case of parts subjected to vibration due to greater deflection and energy absorption.

In cases of application of the light metals where they are subjected to buckling and bending stresses, the moment of inertia is a decisive factor and since the size of section in this case is calculated as the square or cube, it follows that sections in magnesium or aluminum alloys can be employed with a substantial weight economy. Maximum weight saving is achieved by increasing the original heavy metal section in geometrical proportion for the lighter metals.

In cases where substitution is required with the same deflection, the dimensions of an aluminum alloy beam must be about 1.3 times that of a steel beam resulting in a weight savings of approximately 40%. However, it is not always necessary to use the same geometric form, and by redesign, it is possible to effect even greater weight economies.

Aluminum Alloys

Aluminum alloys have many properties that make them particularly suited to lightweight construction. Both cast and wrought materials are important, with the wrought alloys used wherever design permits because of their generally better properties. The ultimate strength of aluminum alloy castings ranges up to 50,000 p.s.i., depending on the use or type of heat treatment.

The wrought forms of aluminum alloys produced are sheet and plate in widths greater than 100 in. and lengths up to 30 ft., wire, rod, bars, tubing, extruded shapes and forgings. Rolled shapes are available in cross-sections up to 30 sq. in. and lengths up to 85 ft. Of particular interest to the engineer are shapes which can be produced to almost any design by extrusion making possible the most efficient distribution of metal for load requirements.

Among the most important considerations are the following:

Light Weight—Aluminum alloys weigh about 0.1 lb. per cu. in., which is a little more than ⅓ the weight of steel, and 60% more than the weight of magnesium alloys.

Strength—Aluminum alloys range in strength from commercially pure aluminum with a yield strength of 5,000 p.s.i. and a tensile strength of 13,000 p.s.i. to the new high strength aircraft alloys 75S-T and R-301 and R-303 with yield strengths up to 80,000 p.s.i. and tensile strengths up to 90,000 p.s.i.

Stiffness—The stiffness factor for a member of given length is expressed as the product of the modulus of elasticity of the material and the moment of inertia of the section. Aluminum alloys have a modulus of elasticity of about 10,500,000 p.s.i. which is a little more than one-third that of steel. Despite this lower modulus of elasticity, stiffness equal to that of a steel part can be obtained by an increase in dimensions of the aluminum part which will still permit an appreciable saving in weight. Sheet or plate panels, for instance, can be as stiff as corresponding steel panels and yet weigh less than half as much.

Toughness—The toughness of a material depends in general on its strength and ductility. Elongation measurements bear some relation to ductility, but are admittedly not a complete measure of this elusive property. Elongation values for wrought aluminum alloys vary from 45% to as low as 6%. The lower elongation values are encountered in some of the high-strength alloys used in aircraft construction. The best demonstration of the adequate toughness of such materials is probably found in the amount of abuse military aircraft are called upon to withstand and still function satisfactorily. Unlike many ferrous alloys, aluminum alloys do not decrease in strength and toughness at low temperatures.

Durability—In general, aluminum alloys have good resistance to corrosion, the resistance varying with the alloy and the exposure conditions. In many applications, advantage can be taken of the increased resistance to corrosion of aluminum alloys as compared with other structural materials. In most structural applications, it is recommended that aluminum alloys be given about the same paint protection as is used with other structural materials. Aluminum alloys are capable of withstanding a great number of repetitions of stress without failure. The absence of fatigue failures in aluminum alloy aircraft structures attests to the adequate fatigue strength of these materials.

Conductivity—The electrical conductivity of aluminum is 64% of the International Annealed Copper Standard on an equivalent volume basis, and on an equivalent weight basis excels copper. Its use as cable and bus-bar for power transmission comprises one of its largest applications.

Aluminum has a thermal conductivity of 0.52 cal. per sec. per sq. cm. per cm. per deg. C as compared to 0.37 for magnesium: This property, together with its light weight accounts for the use of aluminum in field kitchens and pistons.

Fabricating Characteristics—The working properties of aluminum alloys are such as to permit them to be fabricated by the methods used with other structural materials. They can be formed on all commonly used blanking, stamping and forming machines. The workability of aluminum alloys decreases with increased strength, as is the case with all metals, but even the highest strength alloys remain readily workable, as is illustrated by the modern airframe.

All aluminum alloys are readily machined at high speeds using the same tools as for steel, although best results are obtained with tools specially designed for aluminum. Plates up to ½ in. can be sheared, but aluminum alloys should not be flame-cut.

The usual methods of joining—riveting, molding, brazing and soldering—are all applicable to aluminum alloys. Either aluminum alloy or steel rivets may be used. Commercial procedures for torch, arc and resistance welding may be easily learned by any competent welder, while brazing and soldering are successfully done using special fluxes.

Magnesium Alloys

Magnesium alloys have several outstanding properties of direct interest to the engineer designing lightweight structures. They are available as castings, with tensile strengths from 20,000 p.s.i. to 40,000 p.s.i. depending on their heat treatment and as sheet and plate; extruded wire, rod, bars, tubing and shapes; and press and hammer forgings. As in the case of aluminum alloys, efficiency of design is often achieved by using extruded shapes.

The characteristics of greatest interest for lightweight design are:

Light Weight—Magnesium alloys, lightest of all the major industrial metals, weigh about 0.065 lb. per cu. in.—less than ¼ the weight of steel. To put it another way, magnesium alloys weigh about 1 oz. per cu. in. as compared to 1.6 oz. for aluminum alloys, 4.5 oz. for steel and 5 oz. for brass and bronze.

Strength—Magnesium alloys can be obtained with tensile strengths as high as 50,000 p.s.i. and a tensile yield strength of 38,000 p.s.i. The compressive yield strength is about ⅔ of the corresponding tensile value.

Stiffness—The modulus of elasticity of magnesium alloys is only about 6,500,000 p.s.i., and yet in sheet or plate construction stiffness equal to that for steel can be obtained by increasing the thickness about 65% and still have a panel weighing less than 40% of the weight of the steel panel.

Notch Sensitivity—The presence of a notch or other stress raiser reduces the toughness or fatigue strength in virtually all materials. Magnesium alloys are somewhat more sensitive to this notch effect than are aluminum alloys. It is therefore advisable to design so as to minimize features that function as stress raisers.

Corrosion Resistance—Magnesium alloys have good resistance to corrosion (better than that of mild steel) when exposed to inland atmospheres and can often be so used without protection. In the presence of salt, however, additional protection must be provided by painting, lacquering, etc. The alloys are highly resistant to alkalies, chromates, borates, fluorides, acid-free oils and fats and gasoline.

Fabricating Characteristics—The processing behavior of magnesium alloys, while differing somewhat from those of other structural materials, are nevertheless such as to permit most fabricating procedures.

All except the most simple forming operations in the softest alloys will require that magnesium alloys be formed hot; that is, at temperatures between 450 and 700 F [see the first article in this issue of M&A for new data on magnesium forgings, and our next issue for information on deep drawing magnesium—Editors].

The ease and speed of machining is one of magnesium's chief attributes—it is indeed the "most machinable" of the commercial metals. To take fullest advantage of this characteristic, tools should be used that are designed especially for the purpose.

Riveted connections in magnesium alloys are generally made with 56S rivets (an aluminum alloy containing about 5 per cent magnesium). These rivets are driven cold except in the larger sizes. Satisfactory commercial procedures have also been developed for torch welding, spot welding, and arc welding magnesium alloys. Arc welding has been considerably expanded through the development of the helium-arc process.

Anyone concerned with the economical application of aluminum or magnesium alloys in lightweight construction must, of course have knowledge concerning the cost of these materials. However, cost comparisons based on unit material costs will mean very little. The only significant comparison of cost is one based on the cost of the finished structure. Experience has indicated that the costs of the alloys of aluminum and magnesium are such that anyone interested in obtaining economical lightweight construction should not overlook the possible application of these materials.

A Materials-and-Methods Article The low-tin solders introduced as a war-emergency tin-saving measure, although not popular with operators, are actually highly useful materials and, when properly understood and then applied with the carefully developed and simple methods and techniques described in this article, may be found as good as the conventional 60/40 solders from both the design and production points of view. The engineering background, best operating practice and some useful design hints for these new solders are presented here, but the information is equally applicable to the other tin-lead solders in commercial use.

Dip bath for soldering copper tubes in automobile radiator cores.

An Engineering Approach to

Soldering with Tin-Lead Alloys—Part I

by **A. Z. MAMPLE** *Assistant to Lines Engineer, Western Union Telegraph Co., New York*

SO MUCH CONFUSION or lack of information was found in literature and other sources during the course of research and development work in connection with efforts to develop low-tin alloys and the methods and technique to insure their successful use, that it appeared desirable to gather the general results of this research into an article of this kind. The statement regarding the confusion in literature is not a reflection on the published data, but is more as J. A. Kies[6] found: "In studying the literature . . . one might easily become confused. . . . This is not a reflection . . . on published data . . . but is a natural consequence of the many variables in soldering and testing not clearly specified when the results are given."

Tin-lead alloys, however, have been used for cen-

turies and yet the characteristics of the alloys seem to be little understood compared to the extensiveness of their use. Even text books give data which are in error or which are presented with resultant misleading information on the alloys.

Practical Misconceptions Exist

In connection with the use of these alloys, so many misconceptions abound regarding different phases of their use that the ultimate usefulness of the product in which the alloy was employed is often destroyed. These misconceptions frequently are the cause of the method being unnecessarily dropped in favor of other more costly methods. It seems rather unusual that such a state would exist regarding the most widely known series of alloys and their application inasmuch as their use in joining metals is probably the oldest and the most common form of metal joining known. With the introduction of electricity, the use of tin-lead alloys became increasingly important as an effective low resistance bond between metallic parts of the electric circuit.

There are probably more people, including technicians, artisans, and the novice, who employ the tin-lead series of alloys to a greater extent than any of the other alloys known. This fact makes it all the more a mystery why misconceptions in the art should abound so freely. That these unusual circumstances and misconceptions exist, one has only to observe the variable results obtained by different workers, examine the workmanship, check on the results of the product involved in the application of the alloys or read the conflicting opinions in technical literature regarding the alloys, fluxes, solderability of metals, effect of temperature, strength of joints, etc. With the shortage of tin due to the war emergency and the introduction of tin-poor solders, the errors have obviously been amplified.

It is the object of this article to provide a basis for obliterating certain prevailing misconceptions regarding the tin-lead alloys and their application, to give the characteristics of the various tin-lead alloys, and to at least clearly picture the right procedure in the application of these alloys. It is also the object of this article to clarify the prevailing misconceptions regarding the functions of a flux. A further object is to show how rosin can be made to perform the functions of the perfect flux although it is now known as a flux which is poor and deficient. But it is the only flux in the world which leaves the perfect flux residue. The relative characteristics of various metals to "take" solder, technique as a function of metal flow, and strength of a joint under various conditions of load and temperature are also discussed.

Melting Behavior of Tin-Lead Solders

Tin-lead alloys have some unusual characteristics which do not appear to be generally known. Tables in textbooks and other sources of data generally give the "melting point" of different tin-lead alloys. Wherever this occurs one should use such data with caution because they are likely to be misleading. Data of this kind have resulted in the widespread assumption that at this "point" or temperature, the alloy changes from a solid to a liquid. This, however, is not the case.

Most tin-lead alloys have three states: A solid state, a semi-liquid state, and a liquid state. In the plastic state the material is soft and "mushy," but still will not flow like a liquid. The three states of the alloys can generally be distinguished by appearance; the liquid is bright and shiny, the semi-liquid is somewhat dull-colored and the solid is still duller with a definite matte finish. The last change is particularly noticeable at the instant of occurrence.

The temperature at which a tin-lead alloy changes from the solid to the semi-liquid state is called the "solidus point" and the temperature at which the alloy changes from the semi-liquid to the completely liquid state is called the "liquidus point."

Table 1 shows the solid and liquid states of most all tin-lead alloys. This table shows that all the alloys of tin and lead have solidus and liquidus points differing from each other and that they are all lower than the melting points of either tin or lead. The table also shows that all of the tin-lead alloys except one have a semi-liquid range. The alloy having no plastic range is the eutectic and has a 62% Sn-38% Pb content and is the only one which has a "melting point" where the solidus point and the liquidus point are the same. The temperature at which the eutectic melts is 361 F.

As the eutectic melting point is also the solidus point for all the tin-lead alloys from 10 to 97.5% practical tin content, it is of interest to know what this correct temperature at the point of change is. So many authorities have given different values for the eutectic melting point and eutectic composition, that it appears as though there ought to be some authority which may provide the basis for an agreement on these values. It may be noted that a value of 361 F and a 62% tin, 38% lead composition is used as the eutectic melting point and composition, respectively, in this article. It is recommended that since several of the leading authorities on the non-ferrous metals, tin and lead, in this country[1] and in Great Britain[2] are in close agreement on this temperature and composition as shown in Table 2, the temperature of 361 F, and the composition of 62% tin, 38% lead be accepted and used as the correct value.

An understanding of the characteristics of tin-lead alloys will bring about a more intelligent use and application of these alloys. This will be better understood by referring to the tables, using as examples an alloy employed as solder prior to the present World War and one used since the beginning of the war. When the characteristics of these are understood, the action of any other alloy may be accurately anticipated by reference to the tables.

In the popular 45% tin, 55% lead solder generally employed before the war, a reference to Table 1 will show that its solidus point is 361 F and its liquidus point is 438 F. If one had looked at one of the tables of "Melting Points of Solder" such as was used in a recent technical book published for reference purposes as late as 1943, he would have found a temperature of 438 F given as the "melting point." If he had expected the alloy to solidify at 438 F he would have found that it would not have solidified at that temperature; in fact, he would have found that it would

Table 1.—Melting Range Data—Solid and Liquid States of Tin-Lead Alloys

Composition %Sn	%Pb	Solidus point, solid below deg. F.	Liquidus point, liquid above deg. F.	Remarks
0	100	621 (620.6)	621 (620.6)	Pure Lead
5	95	556 (518)*	594	(1)
10	90	500 (361)*	572	—
15	85	428 (361)*	550	(1)
19.5	80.5	361 (1)	535	Eutectic Limit[1]
20	80	361	531	(1)
25	75	361	511	(1)
30	70	361	496	—
35	65	361	477	(1)
40	60	361	460	—
45	55	361	438	—
50	50	361	421	(1)
55	45	361	399	(1)
60	40	361	375	—
62	38	361	361	Eutectic[1, 2]
65	35	361	367	(1)
70	30	361	378	—
75	25	361	387	(1)
80	20	361	399	(1)
85	15	361	410	(1)
90	10	361	423	—
95	5	361	437	—
98	2	361 (1)	441	Eutectic Limit[1]
99	1	414	446	—
100	0	450 (449.6)	450 (449.6)	Pure Tin

*Note: The Nat. Lead Co.'s research laboratory recommends that, for engineering design purposes, solidus temperatures of 518 F, 361 F and 361 F be used for the 5-95, 10-90 and 15-85 alloys, respectively. Values in the table are equilibrium values except those in parenthesis marked with an asterisk.

not solidify until a temperature of 361 F was reached.

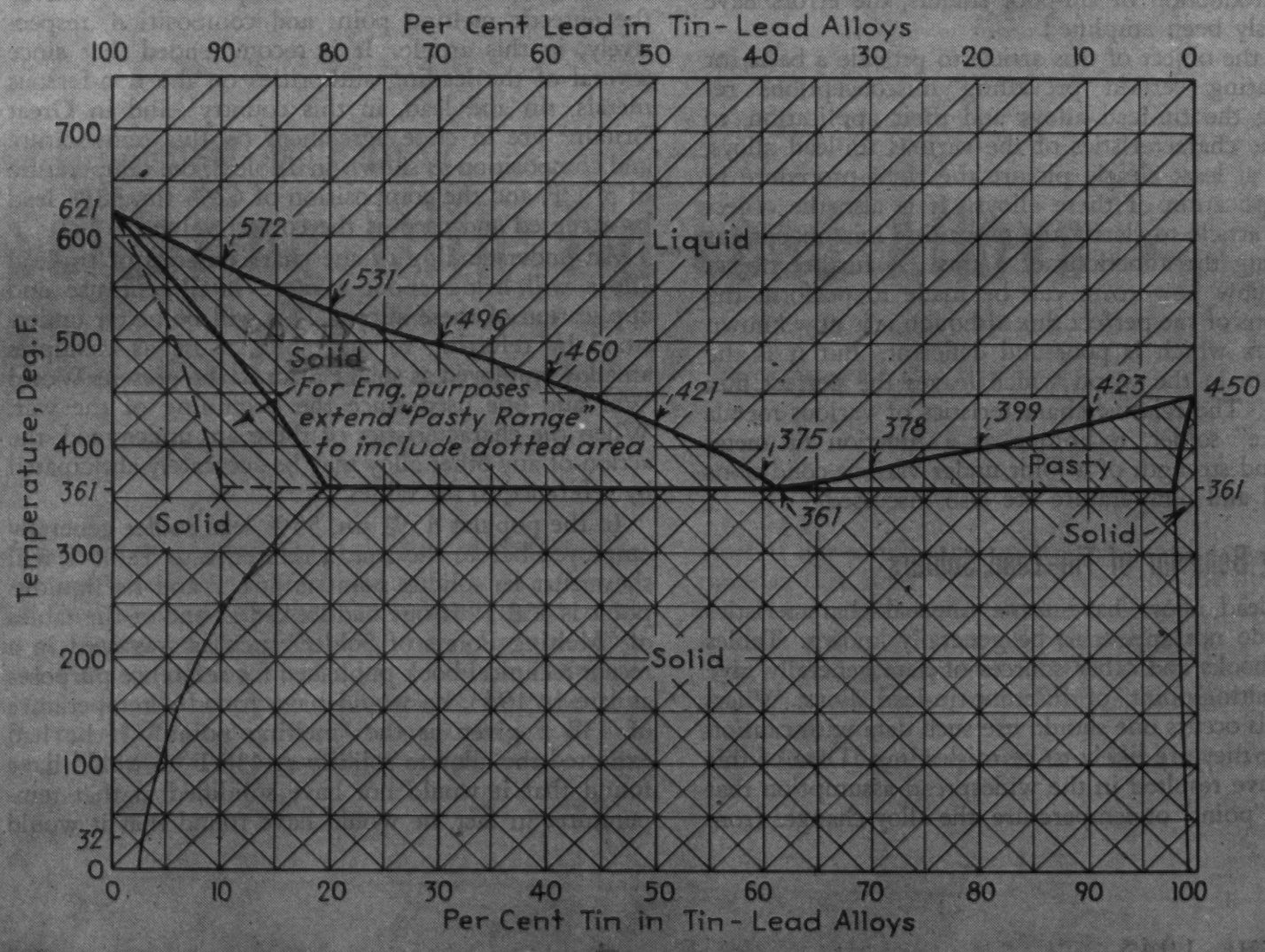
An understanding that this characteristic is variable for different tin-lead alloys is necessary for their successful application as will be readily appreciated. In soldering, both of the surfaces to be joined, as well as the solder alloy, must be raised above the liquidus point of the particular solder to wet the surfaces and to alloy with the base metal. It must then be left to cool, without movement of the parts until it has cooled to the solidus point. Relative movement of the parts being soldered while at a temperature above the liquidus point does no harm and movement below the solidus point is, of course, impossible. Between these two points, however, is a critical semi-liquid range of the solder alloy which is neither entirely solid nor liquid.

A 45/55 solder, according to Table 3, has a semi-liquid range of 77 F. This range is equivalent to a time period for it means that a period of time must elapse long enough for the solder and the article soldered to cool corresponding to a drop in temperature of 77 F. This temperature drop is 77 deg. lower than the liquidus point and is 77 deg. *below* the temperature given by many textbooks as the solidifying point. To this range, of course, must be added the time required to cool the solder from the maximum reached above the liquidus point to the liquidus point. Any movement of the solder while cooling in the semi-liquid range will probably result in a defective joint, both electrically and mechanically.

Behavior of the 20/80 Solder

If we now consider one of the solder alloys adopted by Western Union, and subsequently adopted as the National Standard by the War Production Board for

Melting and Freezing Ranges of Tin-Lead Alloys.



general soldering purposes, namely the 20% tin, 80% lead alloy, we can better see what has taken place in the substitution and what must be done to make the use of any substitute alloy successful.

According to Table 1, the 20/80 alloy has a solidus point of 361 F and a liquidus point of 531 F. If the designer expected the 20/80 solder to solidify at 531 F, he would find that it will not solidify until the solidus point of 361 F was reached. It should be noted that this is the same temperature at which the 45/55 solder solidified, namely at 361 F. A reference to Table 3 will show 20/80 as having a semi-liquid temperature range of 170 F.

It should now be noted that even though the semi-liquid range of 20/80 alloy is 170 F, it is necessary to raise the temperature of solder and the article being soldered only 93 deg. higher than previously, not 170 F. Inasmuch as the solidus points of both solders are the same, the critical cooling off period is greater with the 20/80 solder than with the 45/55 as represented by the difference in the respective semi-plastic ranges for the two solder alloys as given in Table 3.

Since, as previously explained, the semi-liquid range is the critical range at which the solder or the article being soldered cannot be disturbed, then a longer period of time will be required for this cooling period as represented by the 170 deg. semi-liquid range and the 77 deg. range for the respective solder alloys. This constitutes the main objection to the use of the lower tin content alloy. With some joints, such as wires being soldered to terminal blocks, with the 45/55 solder the critical cooling period was relatively short so that the operator may not have been conscious of a critical range, but with the 20/80 solder a somewhat longer cooling period must be allowed. However, this difficulty may be overcome by not moving the articles during the cooling period or by clamping or fastening them so that no movement can take place during the cooling in the plastic range.

Actual Heat Requirements

Another misunderstanding regarding tin-lead alloys and in particular tin-poor alloys, is the amount of heat required in their use. Because the liquidus point is somewhat higher (see Table 1), it is assumed that considerably more heat is necessary with tin-poor solder alloys. While a slightly higher temperature is required for a 20/80 alloy, actually less heat is required per pound of 20/80 alloy than is required for a 50/50 alloy. A reference to Table 4 will show that to heat one pound of alloy from 60 to 100 F above the liquidus point, 45.7 B.t.u. of heat are required for 50/50 alloy, while only 38.5 B.t.u. are required for 20/80 alloy.

This is important to understand because it can be seen that since a lesser amount of heat is necessary, soldering small clips and similar articles requires less total heat than was required with the higher tin content solders. Many operators have purchased new equipment in order to obtain more heat and higher temperatures because the "melting point" tables seemed to indicate that more heat was necessary, whereas the only justification for such a conclusion would be in cases where large objects were to be soldered. The hotter heating units tend to increase soldering difficulties rather than decrease them as will be shown later.

It might be well to point out that our tests showed that the 50/50 solder spreads no better on copper at the lower soldering temperatures than the 20/80 does. It has been shown, however, that the 50/50 solder does spread better than the 20/80 at elevated temperatures, but spreading at elevated temperatures is of no advantage in most electrical work since solder spreading down on clips, terminals or wires often injures adjacent insulation and is a waste of material. A 50/50 solder is of advantage only where close fitting joints or sweating operations are involved and where heating is difficult and the longer cooling time is not a production handicap.

Production engineers would do well to take note of these factors and reduce the volume or design of soldering clips so as to use and dissipate a minimum of heat and at the same time employ the proper solder alloy with a proper balance for B.t.u. required per

Table 2.—Tin-Lead Eutectic Composition and M.P. Temperature

Composition		Melting point, Temp. deg. F.	Reference
Tin%	Lead%		
62.00	38.00	361.00	
62.00	38.00	361.40	(1)
62.00	38.00	361.40	(2)
61.86	38.14	361.94	(3)
—	—	358.00	(4)
63.00	37.00	360.00	(5)

Table 3.—Pasty (Semi-Liquid) Temperature Range of Tin-Lead Alloys

Alloy %Sn	%Pb	Temperature limits, lower deg.F. Solidus(A)		upper deg.F. Liquidus(B)	Pasty Temperature range (B-A) deg. F. above solidus Pt.	
0	100	621	to	621	0	Lead
5	95	556(518)*	to	594	38(76)*	(1)
10	90	500(361)*	to	570	70(209)*	(1)
15	85	428(361)*	to	550	122(189)*	(1)
19.5	80.5(1)	361	to	535	174	—
20	80	361	to	531	170	(1)
30	70	361	to	496	135	—
40	60	361	to	460	99	—
45	55	361	to	438	77	—
50	50	361	to	421	60	(1)
60	40	361	to	375	14	—
62	38	361	to	361	0	Eutectic
70	30	361	to	370	17	(1)
80	20	361	to	399	38	(1)
90	10	361	to	423	62	(1)
95	5	361	to	437	76	—
98	2(1)	361	to	441	71	—
99	1	414	to	446	32	—
100	0	450	to	450	0	Tin

*Note: Nat. Lead Co.'s research laboratory recommends for practical engineering purposes that solidus temperatures of 518 F, 361 F and 361 F be used for the 5-95, 10-90, and 15-85 alloys respectively. They accordingly recommend pasty temperature range values of 76 F, 209 F and 189 F respectively, for these three alloys. All values except those in parentheses are equilibrium values.

pound, pasty range and liquidus point as well as other factors of strength, spread, etc. If all factors were taken into consideration by the production engineer, the human element would become less important, the work more economical and the production more consistent.

Production engineers would also do well to look into many similar production difficulties. For example, in plating metals by the hot dip process, difficulties are often encountered due to the alloy cooling as the process continues. It is the practice to "up" the processing temperatures of the pot of tin or tin-lead alloy in such cases. Much grief would be avoided if, instead of a higher temperature, more B.t.u. were supplied by employing a larger pot of metal at the normal working temperature. A larger quantity of metal at a lower temperature will better maintain a uniform supply of heat at a uniform temperature. Higher operating temperatures more readily oxidize the hot metal and the base metal, adversely affect the efficacy of the flux, increase operating costs, weaken the joint, etc.

Table 4.—Specific, Latent & Total Heat Tin-Lead Alloys,—B.t.u. per lb.

Alloy %Sn	Alloy %Pb	Mean Sp. Heat: 60 F to liquidus	Mean Sp. Heat: Liquid	Latent heat of fusion	Total heat in liquid at 100 F above liquidus B.t.u.
100	0	0.069	0.060	24.9	57.8[1]
69.5	30.5	0.0579	0.0516	30.6	53.76
50	50	0.051	0.046	23.0[1]	45.65
37	63	0.044	0.041	14.8	43.3
20	80	0.0394	0.0376	16.2	38.5
0	100	0.032	0.032	9.9	31.1[1]

Solderability of Base Metals

Considering now the metals to be soldered, there are three factors which affect the facility with which the joint can be made. These are (1) the characteristic or ability of the metal to be wet by the liquid solder and to alloy with it; (2) the surface coatings which tend to resist soldering; and (3) the relative ability of the metal to conduct heat.

It is well recognized that certain metals "take" solder more readily than others. Chapters could be written on the subject because "take" involves so many factors, but in this article only data of immediate value to production engineers and others will be given. Table 5 gives the relative solderability of certain base metals to "take" solder with the metals arranged in the descending order of their solderability.

Table 5.—Order of Solderability of Base Metals

1. Silver	6. German silver
2. Copper	7. Zinc
3. Brass or bronze	8. Cadmium
4. Tin	9. Iron
5. Lead	10. Steel

It will be noted that the position of the metals closely follows their position in the electrochemical series.

The ability of a metal to conduct heat is a factor in soldering, being of considerable importance when soldering large pieces of metal, but of minor importance in small pieces save where they are in close proximity to materials, like rubber insulation, that give off pernicious gases. As pieces of increasing size and weight are soldered it becomes increasingly necessary to supply adequate heat at the juncture and particularly is this so where the metals have a high rate of heat conductivity. Such additional heat can best be secured by using a larger soldering iron, rather than by a hotter small iron. It is sometimes helpful in soldering large pieces to apply heat, as by a flame, to the parts, but at a point a little removed from the actual point of soldering (pre-heating). The ability of metals to conduct heat is shown in Table 6 arranged in the descending order of conductivity.

Table 6.—Order of Heat Conductivity of Metals

1. Silver	6. Cadmium
2. Copper	7. Iron
3. Zinc	8. Tin
4. Brass	9. Steel
5. Nickel	10. Lead

Coatings

Table 5 is of value and is often used by the designer or worker when soldering to base metals, but it is frequently ignored when metals are to be plated such as where improvement of a base metal is necessary for appearance purposes and to improve its solderability. An example of this is cadmium. Cadmium is next to iron and steel in its ability to "take" solder, yet cadmium is often plated on copper or brass (see Table 5). This may have improved its appearance, but it has decreased the ability of copper to take solder relatively to that of iron.

Further, since cadmium has a melting point approximately equal to that of lead, the cadmium is frequently dissolved in the solder alloy so that the soldering operation is thus actually worse than if the soldering had been done directly to the copper. It then appears that the principal benefit which can be derived from such plating is in the improved appearance of the cadmium or in the relatively slower rate of surface corrosion of cadmium as compared to copper. Basically, the benefit primarily is in the ease of electro-plating since cadmium plating is effective on all surfaces even if small parts touch each other.

Another factor in metal coatings is that electro-deposited coatings are a questionable aid in soft soldering operations. For example electro-deposited tin coatings are difficult to solder, and the bond between the tin and copper is poor. On the other hand hot tin dipped coatings are easy to solder to, and the bond between the tin and copper is excellent. Numerous tests have supported this conclusion. Electro-plated tinned copper has acted so badly that defective joints have resulted. Investigation showed that the solder had not taken satisfactorily to portions of the electro-plated surfaces, but had taken perfectly on adjacent hot dipped surfaces. Tables 7, 8 and 9 reflect the effect of plating in some cases on the strength of the joints. Unplated iron joints made with 50/50 solder show a strength of about 40% greater than joints made from plated iron. This is hardly what one might have anticipated. To obviate such troubles on electro-tinned iron, the coatings are subsequently

heated to diffuse the tin into the iron.

Surface coatings on metals which resist soldering may be divided into "made" coatings and natural coatings. "Made" coatings include enamel, varnish, and other non-solderable coverings. Soldering fluxes in general will not remove such coatings, and articles covered with them must be scraped, filed, sandpapered, or otherwise cleaned to a satisfactory surface before soldering is attempted. The author has been advised that a rosin compound has been developed which removes enamel coatings and at the same time fluxes the copper for soldering.

The natural coatings are the oxides, sulphides, carbonates, etc., of the base metal. These are generally caused by natural conditions, but might be divided into those which occur through the lapse of time, and those which are caused by the very act of attempting to solder. The oxides are the principal of such coatings and are generally removed by a proper flux while soldering is being performed. The sulphides are found less frequently, but are very troublesome when encountered. These coatings may be formed on a clean base metal in the soldering process. For example, the oxides form more readily as the temperature increases. This too is the reason for the easy soldering when using a flux which melts and flows at low temperature, thus excluding the air from the parts as their temperature rises toward a point where they might otherwise oxidize.

The sulphides likewise may be formed in the soldering process or in the course of time on materials stored in the presence of sulphurous fumes. In the communications and power business, probably the most troublesome sulphides arise from the fact that all rubber insulation has sulphur in it and especially when heated gives off sulphurous fumes. In soldering a rubber-covered wire whose insulation is stripped but a short distance, if the wire is heated before the flux has covered it, the wire may readily become contaminated with sulphide and cause great difficulty or even preclude the making of a satisfactory joint until the surfaces have been scraped clean.

Table 7.—Breaking Strength of Lap Joints[6]—Joints with Fillets

Sheet metal	Lap joint	Sq. In. (Joint)	Breaking load-lbs. 50/50	Breaking load-lbs. 20/80	Ave. no. tests
Copper (0.094")	Single	0.56	1750	1700	4
Brass (0.063")	Single	0.56	2570	2690	4
Iron-black (0.062")	Single	0.56	2100	2120	4
Copper (0.094")	Single	0.28	1310	1190	4
Brass (0.063")	Single	0.28	1450	1450	4
Iron-black (0.062")	Single	0.28	1400	1320	4
Iron-galv. (0.065")	Single	0.28	1370	1240	4
Iron-tinned (0.032")	Single	0.28	1070	1010	4

Note: See Table 8 for short time loads on joints—unit strength values as affected by temperature, alloy composition and base metal.

See Table 9 for continuous loads on joints—unit strength values as affected by temperature, alloy composition and base metal.

Table 8.—Short-time Loads for Soldered Joints—Single Lap Joint (See Notes 1 and 2)

Base Metal	Short-Time Load, Maximum safe load-p.s.i. Load @ 70 F. 62/38	20/80	Load @ 180 F. 62/38	20/80	Load @ 362 F.[4] 62/38	20/80
Copper[1]	4420	2100	1020	425	0	0 ([3])
Copper[2]	——	3750	——	——	0	0 ([3])
Brass[1]	6950	3300	1620	670	0	0 ([3])
Brass[2]	——	3550	——	——	0	0 ([3])
Iron-Bl[1]	5450	2600	1260	520	0	0 ([3])
Iron-Bl[2]	——	3200	——	——	0	0 ([3])
Iron-Tin[1]	4000	1900	——	380	0	0 ([3])

[1] Thin sheet metal members—bend under load—shear angle 173 deg.
[2] Heavy metal members—no bend under load—shear angle 180 deg.
[3] 361 F is the solidus point at equilibrium for alloys containing 19.5 to 98.0% tin. For engineering design purposes the solidus point may well be taken as 361 F for alloys containing 10 to 98% tin. See Table 1 for limits of all tin-lead alloys.
[4] 362 F is used to avoid confusion of the state of the alloy at 361 F. With a deficiency of B.t.u. at this point, the temperature of the alloy could be 361 F and yet most of the alloy be in a solid state.

Table 9.—Continuous Loads—Soldered Joints—Single Lap Joint (See Notes 1 and 2)

Base Metal	Continuous Loads, Maximum safe load-p.s.i. Load @ 70 F. 62/38	20/80	Load @ 180 F. 62/38	20/80	Load @ 362 F.[4] 62/38	20/80
Copper[1]	570	275	—	105	0	0 ([3])
Copper[2]	785	375	—	175	0	0 ([3])
Brass[1]	630	300	—	87	0	0 ([3])
Brass[2]	730	350	—	150	0	0 ([3])
Iron-Bl[1]	520	250	—	100	0	0 ([3])
Iron-Bl[2]	680	325	—	135	0	0 ([3])
Iron-Tin[1]	——	210	—	95	0	0 ([3])

[1] Thin sheet metal members—bend under load—shear angle 173 deg.
[2] Heavy metal members—no bend under load—shear angle 180 deg.
[3] 316 F is the solidus point at equilibrium for alloys containing 19.5 to 98.0% tin. For engineering design purposes the solidus point may well be taken as 361 F. for alloys containing 10 to 98% tin. See Table 1 for limits of all tin-lead alloys.
[4] 362 F is used to avoid confusion of the state of the alloy at 361 F. With a deficiency of B.t.u. at this point, the temperature of the alloy could be 361 F and yet most of the alloy be in a solid state.

(To be concluded)

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Extruding Large Nickel Alloy Tubing

A PICTORIAL ARTICLE

The 4000-ton extrusion press is just left of the center of the picture, with a rotary furnace for heating the billets at the right. On the rack in the immediate foreground are mandrel holders of various sizes and designs.

A Methods Article The world's largest extrusion press for high-melting-point alloys like nickel, Monel, Inconel, brass, etc., is the central feature of this story-in-pictures, which shows the operating principles and the production steps followed in extruding these tough materials at the International Nickel Co.'s Huntington works.

Here are mandrels and dies for extruding. In the foreground is a cap that fits on the end of the mandrel. The cap, or piercing nose, drops off the mandrel when piercing is completed.

THE LARGEST EXTRUSION PRESS in the United States for handling high melting point metals is located at the Huntington, W. Va. Works of The International Nickel Co. With 2500 tons pressure on its main ram and 1500 tons on the piercer, it rates a total of 4000 tons, surpassed only by 5500-ton extrusion presses which, however, work on aluminum and magnesium alloys. Largest tubes produced to date have an I.D. of 7.9 in. and an O.D. of 8.9 in. Metals so far handled on this press are: Nickel, Monel, Inconel, gilding metal and copper. However, it is an intermediary process, followed by work on a cold draw bench which gives the material its final desired physicals.

The typical billet, or raw material, is cylindrical, 11⅞ in. in diam. and 18 in. long, and preheated in a Surface Combustion rotary-hearth furnace (to 1670 F for gilding metal being fabricated into rotating bands for shells when we visited the plant). The two chief operations are piercing the billet by a mandrel or piercer that slides in and out of the pressing stem; and extrusion, wherein the stem forces the pierced billet through a round die. Thus the O.D. is regulated by the bore of the die, whereas the I.D., by the size of the mandrel that pierces the billet.

Hydraulic pressure is obtained from city water plus 1% soluble oil. Building up the pressure are two horizontal triplex pumps, each driven by a 400-h.p. motor. The water is pumped into an air-loaded accumulator, connected to the operating valves of the press.

A feature of this press is the "die closing plate" that is securely locked behind the container in which is the freshly-placed hot billet. This makes it possible to perform a preliminary cupping operation on the billet, causing the metal to extrude back over the mandrel without loss of the metal slug which would otherwise go through the large die. After cupping, the plate is lifted out and the die placed against the container, permitting piercing to be completed and extrusion to be made.

Hitherto, nickel, Monel and other high nickel alloy tubing have been produced in this country by piercing, then cold drawing. Some alloys, such as "K" Monel, can not be pierced, hence can not be made as seamless tubing, with equipment in this country.

Extrusion provides a wide range of sizes and a high quality shell for cold drawing. The conversion of the billet into a tube is being achieved at relatively high temperature (up to 2200 F for some special alloys) in the shortest possible time. It is a question of applying great force as fast as possible from a production standpoint and in order to obtain maximum tool life. This new press is expected to open new fields for new alloys in tubing, rod and other solid shapes.

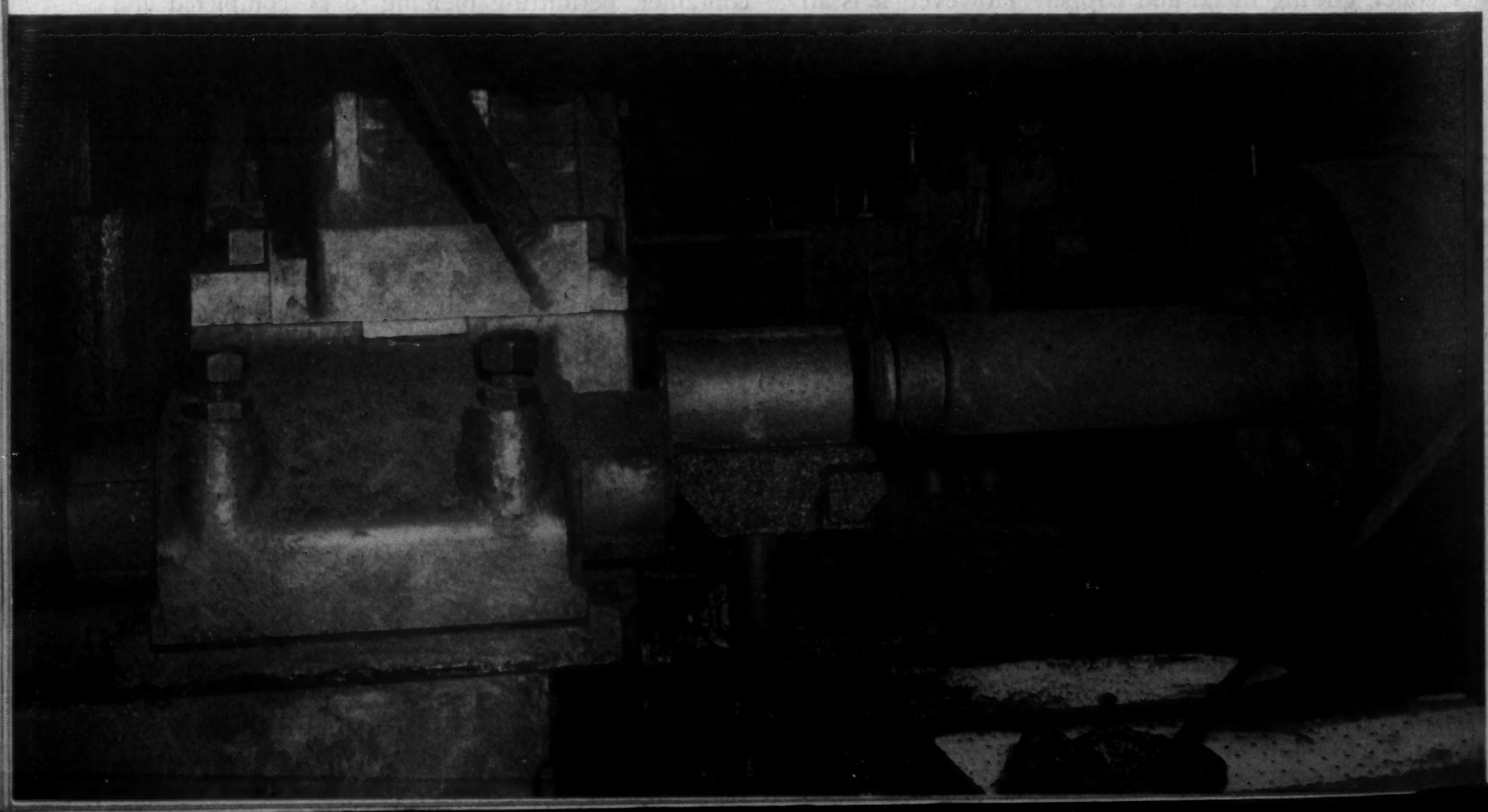
The extrusion press and equipment were designed by Hydropress, Inc., 570 Lexington Ave., New York.

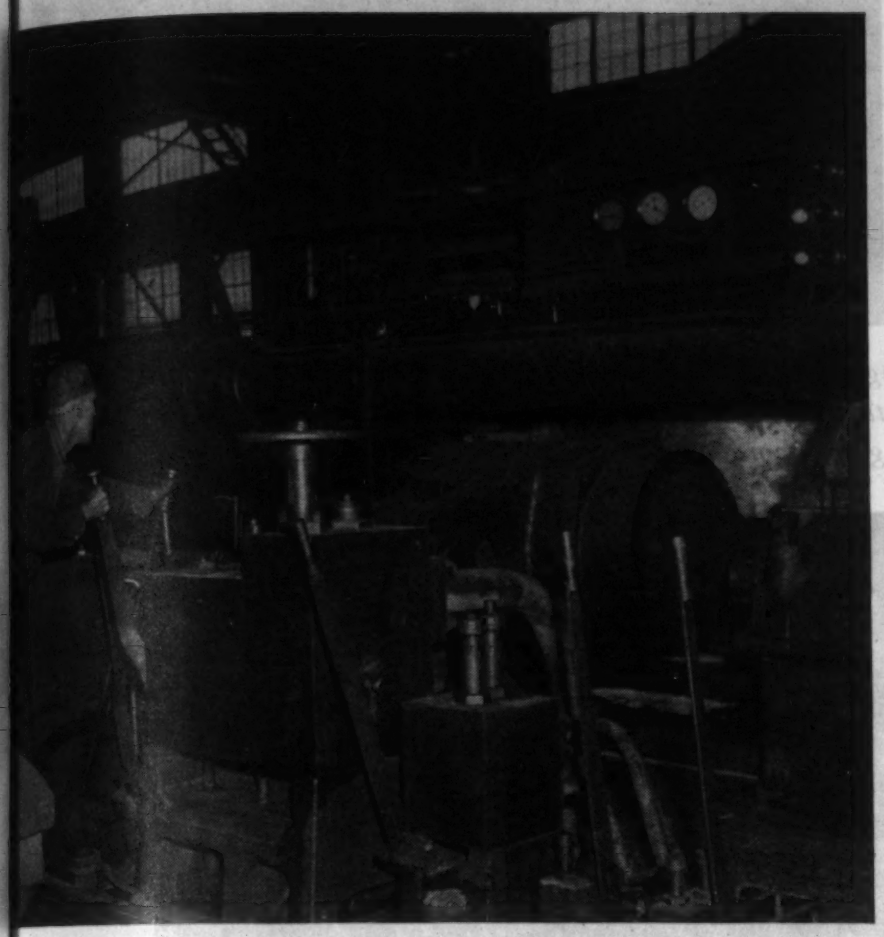
—H. A. K.

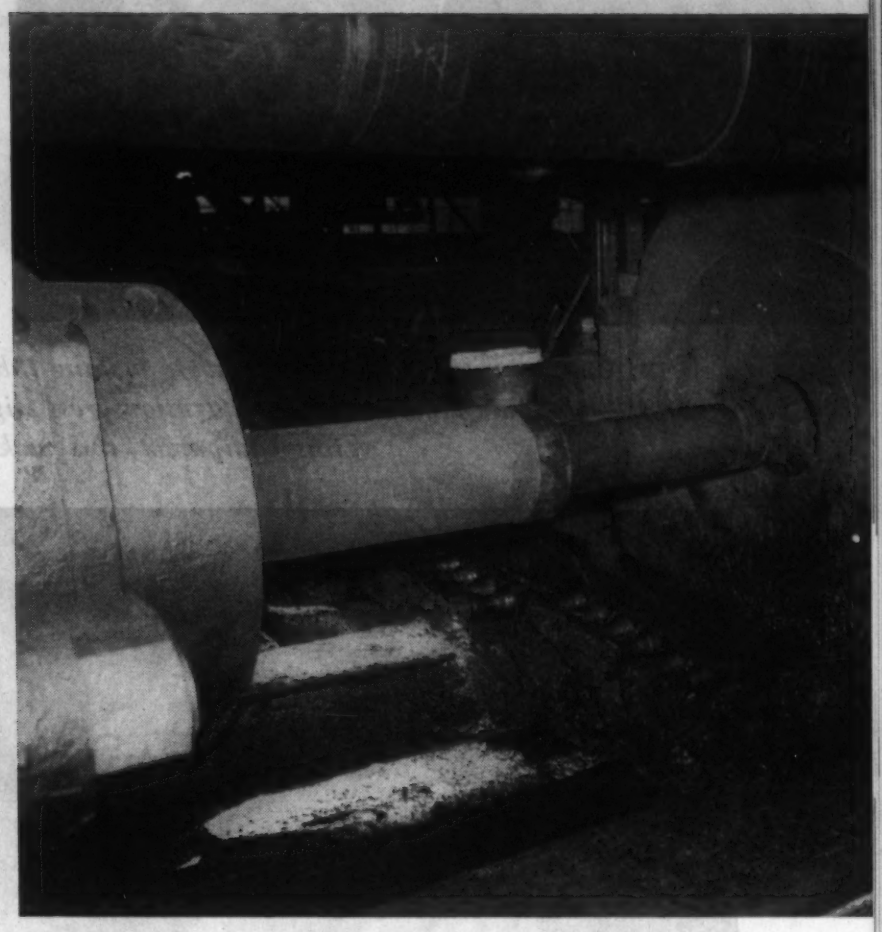
Cold billets are loaded onto gravity conveyor for feeding to the furnace. Gilding metal billets are brought in from an outside brass plant. Nickel-alloy billets are made by the Nickel Co.

Billets are being charged into the furnace.

A billet has left the furnace and been placed on a conveyor. Then an elevator platform (on which the billet here rests) catches the billet, rises, and turns 90 deg. The mandrel is in position to push it into the extrusion press container, which is enclosed in a split casting.

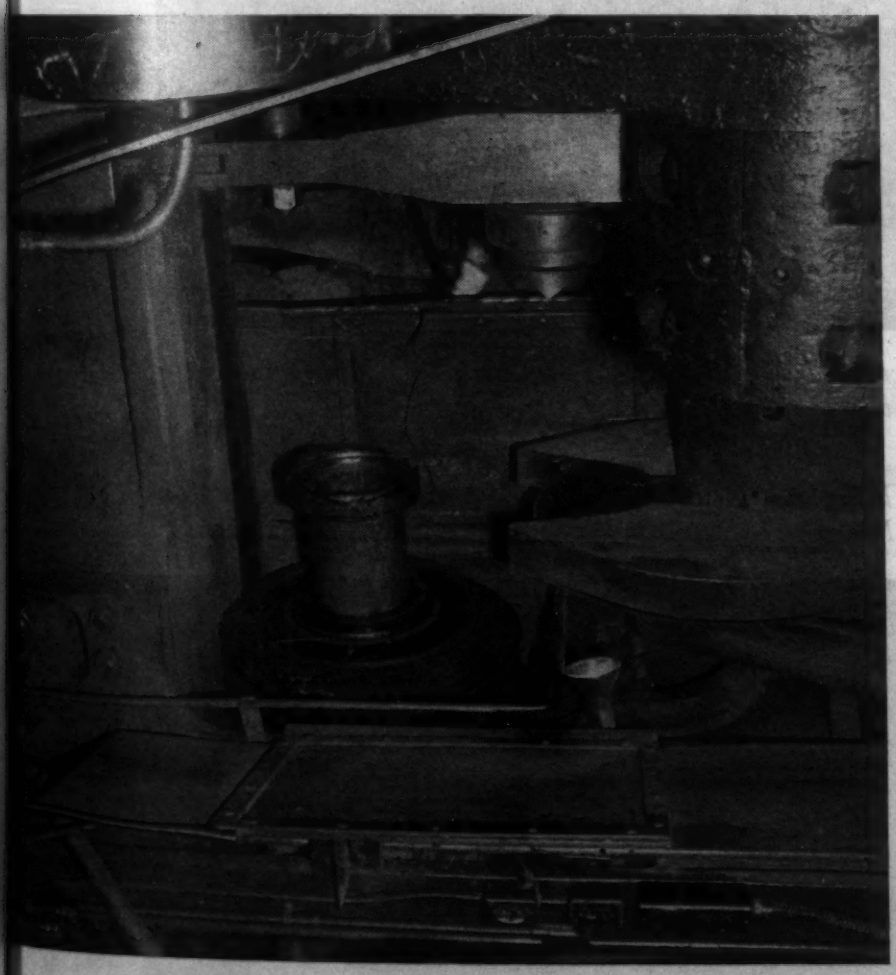


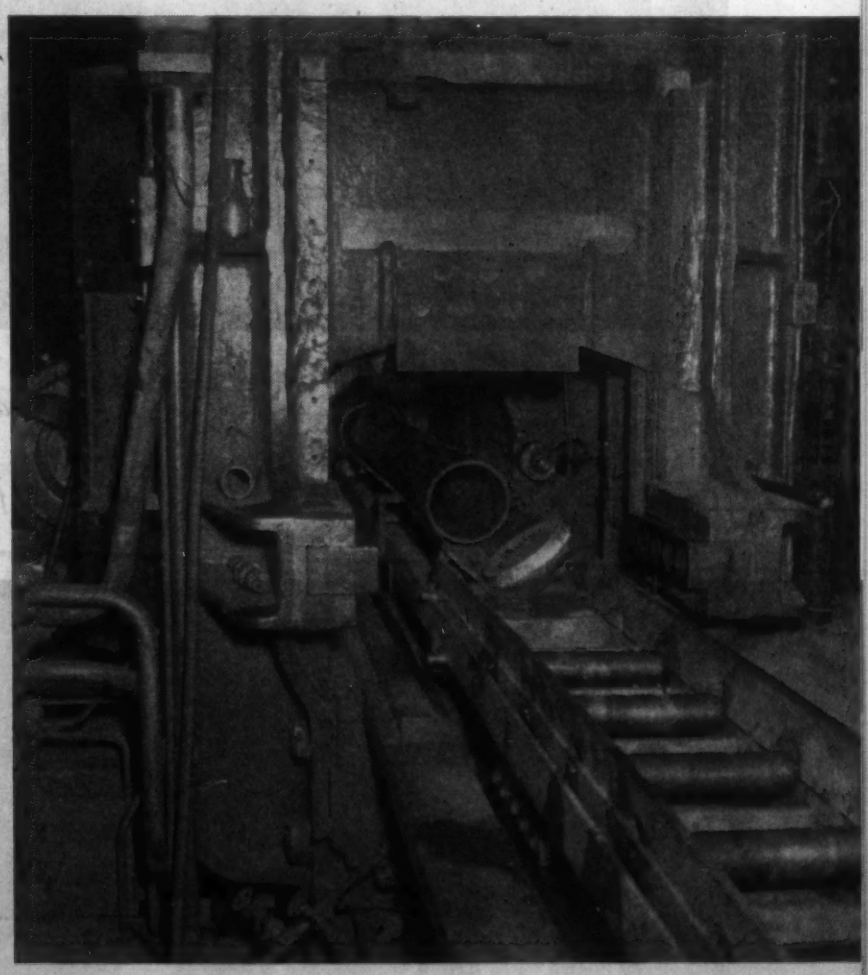


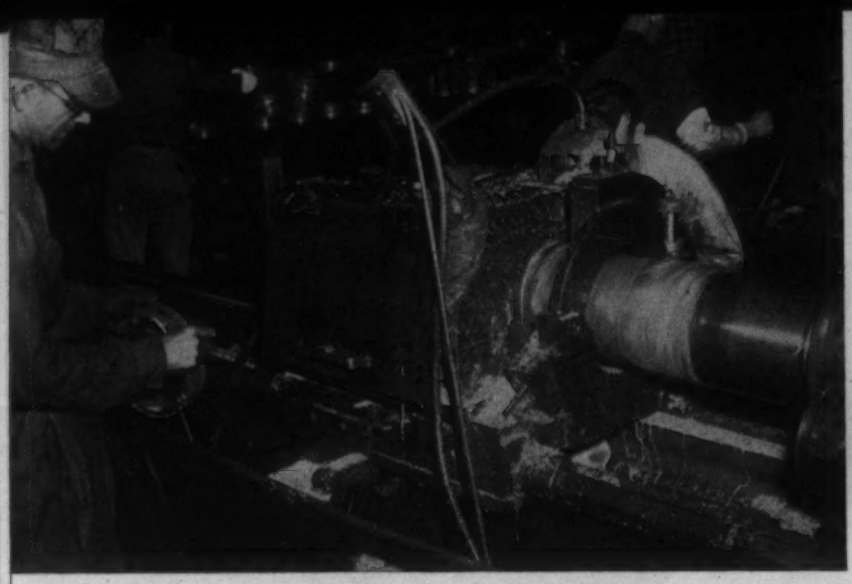


Left: The press is being started for extrusion. Right: By now the billet is shifted in the container and ready for the extrusion operation.

Left: A saw is descending to crop off the unextruded part of the billet. Right: The extruded tube leaves the die.



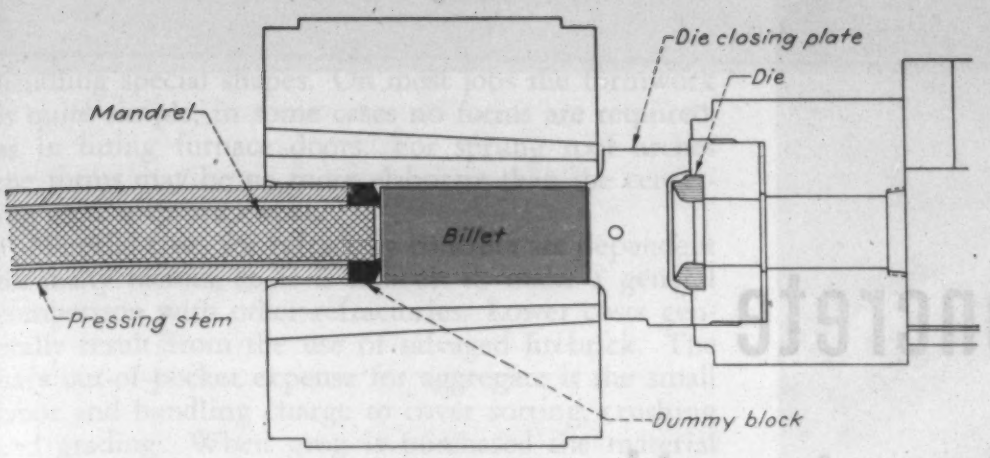




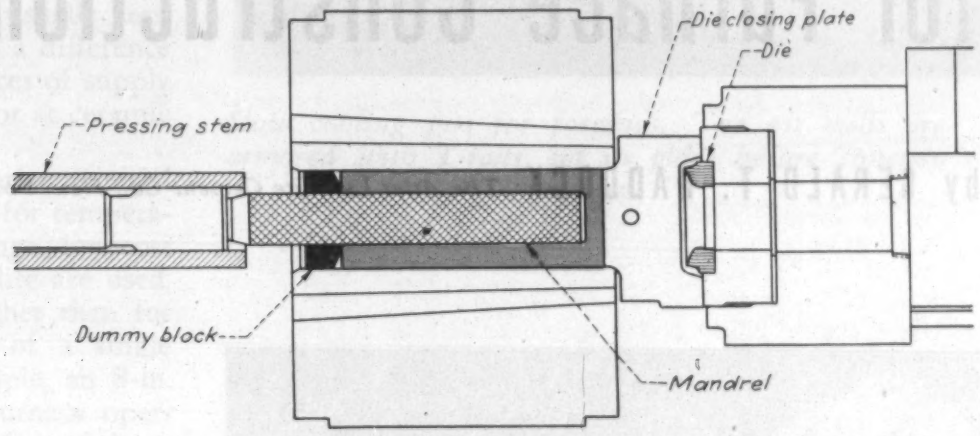
Left: When we visited the plant they were making tubing to be sawed into rotating shell bands for 8 in. guns. Right: All bands are produced on the extrusion press slightly under final size and then expanded hydraulically by this equipment, this making for more precise size.

The extrusion is only an intermediary process. Here extruded Monel tubing is being pointed preparatory to cold drawing.

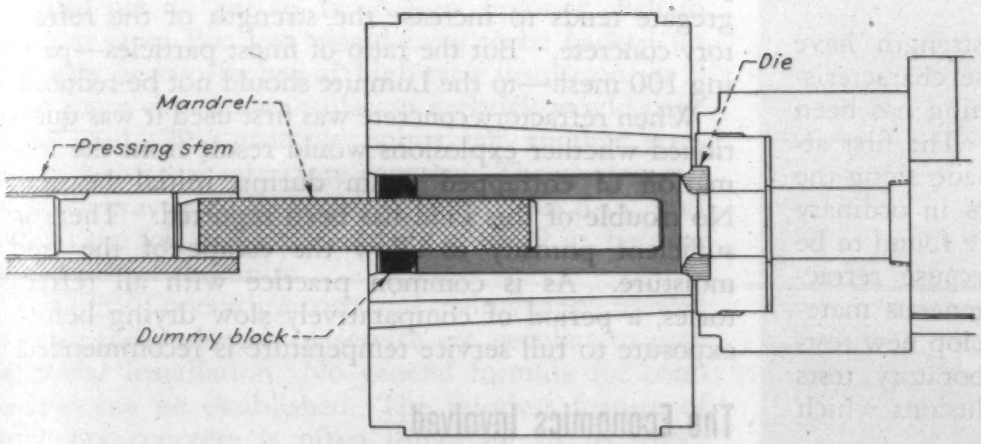
Here is extruded and cold drawn Monel tubing; 26 ft. long, 5-9/16 in. O.D., with ¼ in. wall, produced for the U. S. Navy.



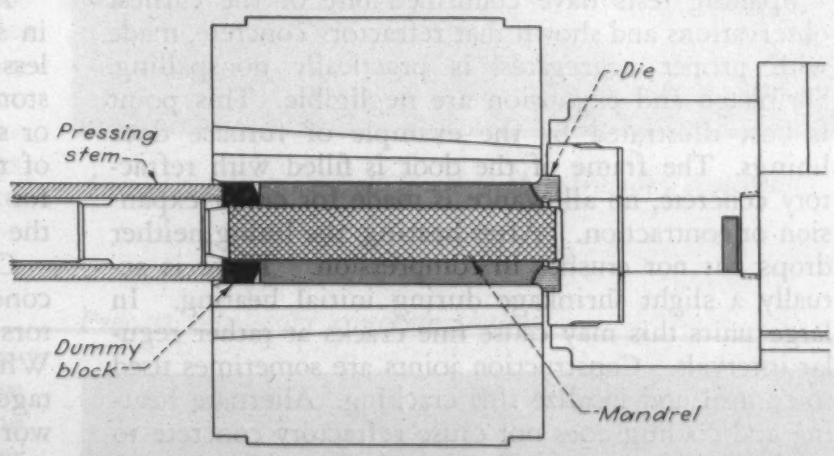
The billet has been shifted into the container and is backed up by the die closing plate which closes the die opening until extrusion is ready to proceed.



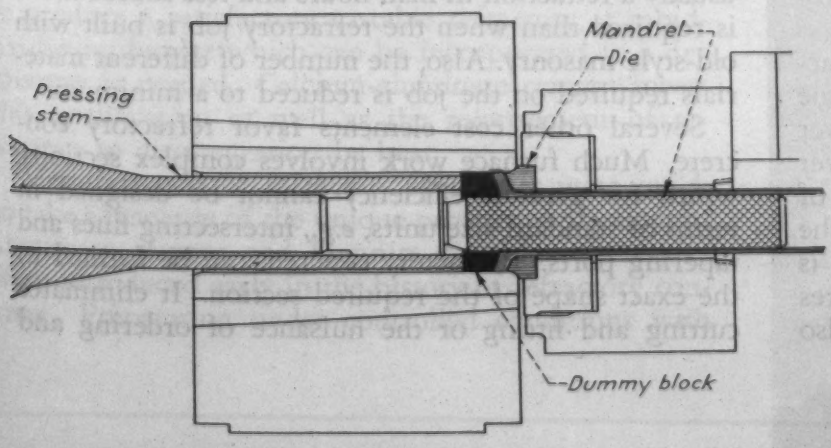
The piercing mandrel advances almost through the billet, while the hollow stem moves backward, the by now elongated billet backfilling the container.



The die closing plate has been lifted and billet and container are contacting the ringed die.



The stem and the mandrel are brought back into the container and complete the piercing of the billet by pushing out the bottom of the cup with metal starting to move through the die opening.



The extrusion stroke is finished, with the tube protruding through the die arrangement, leaving a short piece of unextruded metal between the die and dummy block, shown in one of the illustrations. During extrusion the press stem and the mandrel advance with the same speed.

A Materials-and-Methods Article The first instalment of Mr. Haddock's article, in our February issue, discussed the nature, varieties and characteristics of refractory concrete. This concluding portion describes several typical applications in the construction of furnaces for the metal-working and allied industries.

Refractory Concrete for Furnace Construction—Part II

by GERALD T. HADDOCK *The Atlas Lumnite Cement Co., New York*

Thermal Properties

The factors affecting compressive strength have been discussed in the paragraphs on the characteristics of refractory concrete. So far, nothing has been said about its actual refractory quality. The first attempts to study these properties were made along the lines followed by the ceramic engineers in ordinary refractory practice. These methods were found to be inapplicable in many cases, mainly because refractory concrete in service is not a homogeneous material. It was necessary, therefore, to develop new testing procedures. By and large the laboratory tests have confirmed and extended the conclusions which had been drawn from field experience.

Spalling tests have confirmed one of the earliest observations and shown that refractory concrete, made with proper aggregates, is practically nonspalling. Shrinkage and expansion are negligible. This point is best illustrated by the example of furnace door linings. The frame of the door is filled with refractory concrete, no allowance is made for either expansion or contraction. After heating, the lining neither drops out nor crushes in compression. There is actually a slight shrinkage during initial heating. In large units this may cause fine cracks at rather regular intervals. Construction joints are sometimes used to control and localize this cracking. Alternate heating and cooling does not cause refractory concrete to crack or disintegrate. It is not affected by atmospheric moisture.

When crushed firebrick is the aggregate, refractory concrete has somewhat higher insulating value than that of the original firebrick, because of lower density. The refractory limit is somewhat lower than that of the firebrick. Although the properties of the concrete are governed by the properties of the aggregate they are by no means the same. This is especially true in the mixes for higher temperatures where the reaction of Lumnite and aggregate also plays a part. Increasing the percentage of large aggregate tends to increase the strength of the refractory concrete. But the ratio of finest particles—passing 100 mesh—to the Lumnite should not be reduced.

When refractory concrete was first used it was questioned whether explosions would result from the formation of entrapped steam during initial heating. No trouble of this kind has been reported. There is sufficient porosity to allow the escape of the free moisture. As is common practice with all refractories, a period of comparatively slow drying before exposure to full service temperature is recommended.

The Economics Involved

A new industrial material can be successful only in so far as it does a job better, more quickly, or at less over-all cost. Ultimate economy is the sole touchstone of value, assuming that no questions of safety or scarcity are involved. The widespread acceptance of refractory concrete and the variety of applications for which it is now employed indicate that it fulfills the requirement of economy.

Construction costs with any kind of monolithic concrete are generally low. This was one of the factors that gave rise to the idea of refractory concrete. Why could not the time- and money-saving advan tages of concrete construction be realized in refractory work? The comparison holds true, because there is usually a reduction in man-hours and less skilled labor is required than when the refractory job is built with old-style masonry. Also, the number of different materials required on the job is reduced to a minimum.

Several other cost elements favor refractory concrete. Much furnace work involves complex sections, which for greatest efficiency cannot be designed in terms of standard-size units, *e.g.*, intersecting flues and tapering ports. Refractory concrete can be formed to the exact shape of the required section. It eliminates cutting and fitting or the nuisance of ordering and

handling special shapes. On most jobs the formwork is quite simple, in some cases no forms are required, as in lining furnace doors. For sprung roof arches the forms may be no more elaborate than the centering used with brickwork.

Material costs for refractory concrete are dependent on many factors, so it is difficult to make a general comparison with other refractories. Lower costs generally result from the use of salvaged firebrick. The only out-of-pocket expense for aggregate is the small labor and handling charge to cover sorting, crushing and grading. When grog is purchased the material cost for aggregate and Lumnite approaches the cost of firebrick and jointing material, but is usually less. The location of the job may make quite a difference in the cost of purchased grog as the sources of supply are ordinarily in large industrial centers or at ceramic plants.

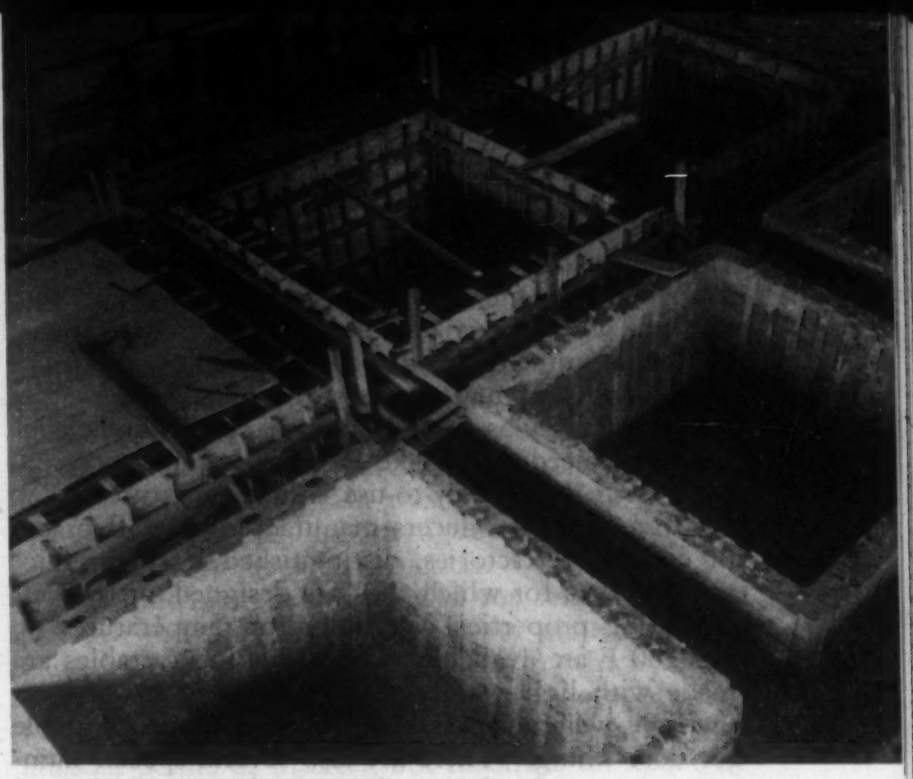
With refractory insulating concrete relative material costs are even more favorable, especially for temperatures of 2000 F and lower. In that range, low-cost aggregates such as Haydite and vermiculite are used, so that material costs usually are no higher than for ordinary refractory concrete. The use of a single material also effects a saving. For example, an 8-in. Lumnite: Haydite concrete wall of a furnace operating at 2000 F will have an outside heat loss of about 726 Btu per hr. per sq. ft. A 9-in. firebrick wall to give the same Btu loss would have to be backed up with one or two inches of high-type insulation, or 9 in. of more expensive insulating firebrick would have to be used. The example points out another cost-saving feature of refractory concrete. The section can be built exactly to fit requirements. If an 8-in. wall will do the job it is not necessary to use 9 in. because of the size of the units.

Savings in operating costs and maintenance, as well as comparative length of service are peculiar to each particular installation. No general formula for comparison can be established. The jointless feature of refractory concrete is often important in its direct effect on operating costs. Elimination of joints cuts down heat loss and prevents infiltration of outside air. In certain forge furnaces this has resulted in marked reduction of scaling. But reduction in direct operating expense through the use of refractory concrete is incidental; the economy on most jobs results from low first cost and low maintenance in relation to the service life.

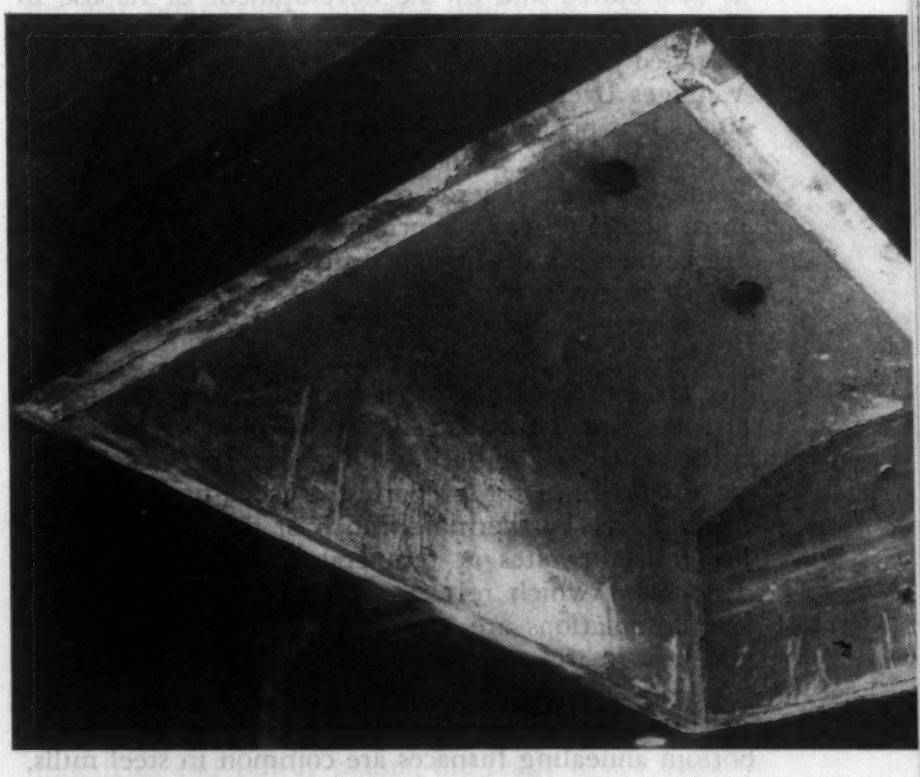
Prepared Castable Refractories

Castable refractories are factory-prepared, dry mixtures of refractory aggregates and cement. They are mixed with water on the job and then handled in the same way as any refractory concrete mixture. In order to produce a satisfactory castable refractory, a rapid-hardening binder which can be incorporated in a dry mixture is needed. Calcium-aluminate cement meets this qualification as well as the requirement of resistance to disintegration by heat.

Manufacturers of refractory specialties were quick to take advantage of the unique properties of calcium-aluminate cement and Lumnite castable refractories were introduced early in the history of refractory concrete. Preparation under controlled conditions with

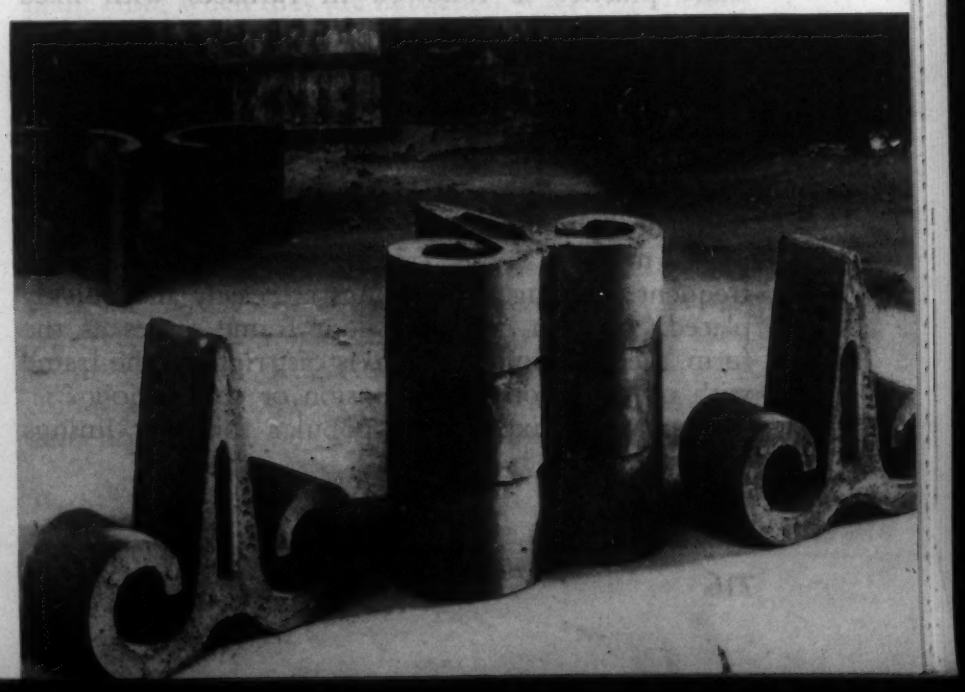


Slow cooling pits for forgings. The pit walls are armored with T-rails, set in place before concrete is cast.



Annealing furnace bell lined with refractory concrete.

Precast refractory concrete shapes.



carefully selected and graded aggregates insures standardized mixes. Castable refractories are especially convenient where it is necessary to keep materials in stock for immediate use on maintenance jobs. The same quality of material is then available for either large or small jobs. A minimum of special knowledge or skill is needed to make high-grade refractory concrete with these ready-to-use castable mixtures.

Most of the producers manufacture several grades of castable refractories, distinguished by the service temperatures for which they are designed, or by their insulating properties. Castables for temperatures up to 2900 F are available. The insulating castables are made with light-weight refractory aggregate producing light-weight concrete which is particularly suitable for door linings. There are also several special Lumnite mixtures for furnace bottoms, burner blocks and other severe conditions.

Typical Installations: Steel Mills

A study of typical installations of refractory concrete will give an idea of the conditions for which it is best suited and of the development of its use in different industries. Obviously, a new material is installed only because it appears to offer definite advantages over the other materials which have been used. It is not put in by force of habit. In most cases it is impossible to obtain accurate cost data from plant operators. Therefore, conclusions as to economy must be drawn from continued use of refractory concrete unless factors other than cost are known to have been effective.

The steel industry is the largest user of refractory concrete. This is due not only to the fact that it is the largest consumer of refractories in general, but also because the mills have waste piles of used firebrick which is suitable for aggregate. They can easily set up facilities for preparing crushed-firebrick grog in quantity. Furthermore, much of the equipment in the mills operates at temperatures and under conditions for which refractory concrete is well suited. The installations are mainly in reheating, annealing and heat-treating furnaces and auxiliaries rather than in the primary open-hearths and convertors.

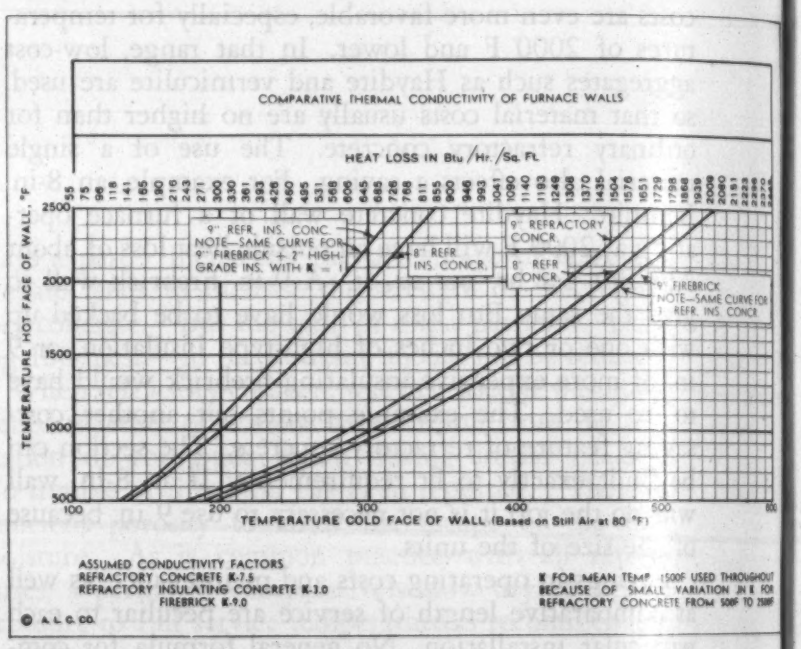
Refractory concrete tops on the hearths of car-bottom annealing furnaces are common in steel mills, malleable plants and forge shops. Refractory insulating concrete is often used to reduce heat loss and lower the temperature of the mechanical equipment beneath the car. Rails or stools may be set in the concrete to hold annealing boxes or large pieces. The same practice is followed in furnaces with fixed hearths.

Furnace-door linings were among the first installations of refractory concrete in steel mills. Their advantages have resulted in their continued use on many kinds of furnaces. The monolithic feature is especially desirable in a lining which is subject to the shock of frequent opening and closing. There are no small pieces to work loose, causing premature failure or frequent patching. The linings are easily and quickly placed. In most cases the door frame serves as the form, the refractory concrete is cast right in the frame with no provision for expansion or contraction.

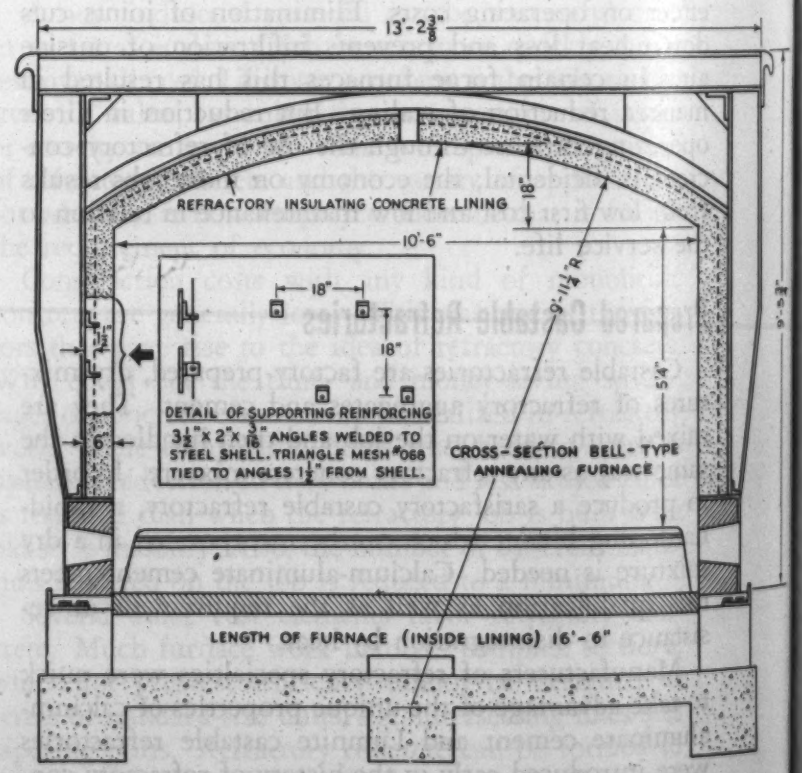
Insulating mixtures are popular for door linings because of the light weight of the refractory insulating concrete, as well as the saving of heat and the protection and comfort of workmen due to lowered temperature in front of the furnace. Diatomaceous earth, Haydite and vermiculite are commonly used for annealing and heat-treating furnace doors where the temperatures are below 1800 to 2000 F. Insulating firebrick grog is used above 2000 F. Where waste insulating firebrick are available they can be salvaged by crushing to aggregate sizes.

In Heat Treating Furnaces

After lining hearths and doors the next step was the construction of refractory concrete roof arches and side walls. The progressive development of refractory concrete is illustrated by the successive installations in a large stress-relieving furnace used for



Thermal conductivity of refractory concretes vs. firebrick.



Cross section of bell type annealing furnace.

treating welded pressure vessels. This furnace is about 80 ft. long, 20 ft. high and 13 ft. wide. Early in 1935 the first refractory concrete was used at the same plant for lining the door of another furnace. The convenience of the material appealed to the plant engineer who decided to try it in replacing a section of the sprung arch on the large furnace. A single arch section 18 in. wide was precast. It had a span of 13 ft. 6 in. and the mix was designed for a service temperature of 2000 F. The arch section was hoisted into position 24 hr. after casting. During the ensuing year more sections of the old furnace roof collapsed or showed signs of distress and were replaced with refractory concrete sections in 1936.

A refractory concrete car top for this furnace followed in 1937. In 1939, sections of the old side walls were replaced with refractory insulating concrete. These sections were 5 ft. wide, 13 in. thick and the full height of the furnace. They supported the original precast roof-arch section. Additional wall and arch sections were placed from time to time until by 1943 practically all of the original refractory had been replaced with refractory concrete, but none of the refractory concrete had been replaced.

Monolithic linings in bell-type furnaces offer the same advantage from the standpoint of handling as monolithic door-linings. The bells can be raised and lowered without disturbing the integrity of the one-piece refractory. One of the big Pennsylvania mills has a large number of furnaces of this type lined with refractory insulating concrete. In placing the lining the top is inverted, reinforcing mesh is spot-welded to the shell, then top arch and sides are cast in place. A light-weight concrete made with insulating-firebrick grog is used.

Slow-cooling pits have been built with refractory concrete walls and refractory insulating concrete covers. Here, also, the covers may be subject to abuse in handling by crane. The jointless lining stays intact because there are no small units to work loose by frequent jarring. The same feature and the convenience of placing are illustrated by the linings in circular annealing furnace covers.

The several examples mentioned give an idea of the variety of ways in which refractory concrete is used in steel mill furnaces. In addition, heat-resistant concrete is used for the foundations of open-hearths and other furnaces where continuous soaking heat would eventually disintegrate ordinary concrete. Refractory insulating concrete and plaster coats of Lumnite with insulating aggregates such as vermiculite are used on the outside of furnaces and checker chambers both to reduce heat transmission and to seal the walls against infiltration of air. In all of these uses the distinctive characteristics of calcium-aluminate cement are essential, *i.e.,* (1) high cold-strength shortly after placing; (2) resistance to disintegration by heat, whether under continuous or intermittent exposure.

In Blast Furnace Plants

Foundations under blast furnaces and footer pads for stoves account for the largest amount of Lumnite used in blast-furnace construction. In both locations the concrete is subject to continuous soaking heat during the entire campaign of the furnace. Heat-resistant concrete insures adequate strength for this service. Crushed firebrick is the aggregate usually employed with Lumnite in making the concrete. The rapid-hardening action of calcium-aluminate cement is an added advantage in this work, as the heat-resistant concrete has high strength in 24 hr. and does not delay subsequent construction.

Lumnite concrete is also used for setting wearing plates at the top of the stack and for grouting cooler plates. There are numerous places in which refractory concrete can aid in the maintenance of blast furnaces and auxiliaries. They do not present any unusual points of interest, but illustrate the economy of refractory concrete. For example, one company follows the regular practice of lining goose-necks with refractory concrete and reports over 60% saving on total labor and material costs.

A bosh was relined with refractory concrete in a southern plant in the spring of 1942. The stack had to be blown in as soon as possible because of pressure for war production. The old lining had been worn back until from 2 to 4 in. of the cooler plates were exposed leaving a very irregular surface. A movable form was built to conform to the desired inside circumference of the bosh. Space between form and old lining was then filled with refractory concrete, using a mix of one part Lumnite to eight parts aggregate by volume. The aggregate was crushed high-grade firebrick graded from dust to 1½ in. maximum.

Complete inspection of the bosh lining will not be possible until completion of the campaign, but reports of examination through cooler-plate openings and apparent performance after about 24 months' service indicated that the lining is entirely satisfactory. The bosh of a second furnace at the same plant was relined with refractory concrete a few months after the first installation.

Other Uses

Refractory concrete is used extensively in coke plants, ceramic plants and oil refineries. In non-ferrous metallurgical plants, forge shops, incinerators, foundries and power plants, the ready-to-use castable refractories are popular because of their availability and convenience.

Attention should be called to the manufacture of special shapes with precast refractory concrete. The advantage of being able to make such shapes with plant labor when they are needed or when opportunity offers is obvious. Perhaps more important is the quality of the shapes, especially when complicated units are needed. There is no distortion because there is no prefiring. The finished shape is the exact size and form of the mold. This results in sharp corners and true plane surfaces. These features are especially important in interlocking units.

The use of calcium-aluminate cement in lining steel stacks is closely allied with the subject of refractory concrete. The linings are essentially refractory insulating concrete. Resistance to corrosion is of great importance and the resistance of calcium-aluminate cement to the action of flue-gas condensate was the

original reason for the use of this cement in chimney linings.

For the typical refractory, insulating, and corrosion-resistant lining, a mixture of Lumnite and an insulating-refractory aggregate such as Haydite is used. Where insulation is not important the aggregate may be crushed firebrick. In either case, the mixture may be cast in place, plastered by hand, or shot on with a cement gun. Reinforcing mesh is attached to the inside of the steel shell, usually by spot welding. Rods or a combination of mesh and rods may also be used. The result is a jointless, smooth lining in intimate contact with the steel.

In War Production

Refractories play an extremely important part in production for war but they rarely get their pictures in the newspapers. The layman is more impressed by the wasteful flames belching from a furnace than by the refractory that makes the heat useful. Even the technical man may not realize the extent to which refractory concrete is aiding war work, because so much of it is buried out of sight in the construction of heating equipment.

Some idea of its importance can be gained from considering that the sale of all calcium-aluminate cement made in the United States was restricted to use for high-temperature concrete in war industries during the period of major war-plant construction (except for small quantities for certain special uses for which no other cement is suitable). At the same time a sufficient quantity of critical bauxite was allocated to the manufacture of the cement in order to insure an adequate supply.

Large quantities of refractory concrete were used in the construction of annealing and heat-treating furnaces in steel mills. Typical examples are the bell-type annealers and the car-bottom heat-treating furnaces shown in the illustrations. In the rebuilding and extension of steel mills for war production, refractory concrete and heat-resistant concrete were used in the construction of slow-cooling pits for ingots and billets, in foundations of open-hearths and electric furnaces, in forge furnaces and in a great variety of special furnaces needed for the new methods of production. Many new batteries of coke ovens were built with heat-resistant concrete footer pads and flues and refractory concrete door linings.

All of these were extensions of applications which had been well developed before the war. In most cases speed of construction was an important factor in addition to the several specific advantages of refractory concrete which have been mentioned. Thus, installations of refractory concrete in a blast furnace bosh was undertaken as a time-saving measure.

In oil refineries and synthetic-rubber plants war uses of calcium-aluminate cement followed practice which had been developed before the war. The use of refractory insulating concrete in heaters, flues, and stacks had then been fairly well standardized. Lumnite went into the construction of a great many plants in the United States and Canada and was shipped to foreign refineries in South America, Russia, and the Persian Gulf.

A unique application of the heat-resistant properties of calcium-aluminate cement in the reconstruction of steel stacks aided in the conservation of steel. The stacks were rebuilt by a special method which consists of constructing a reinforced chimney of gunited concrete around the outside of the old stack. A 2-in. coating of Lumnite heat-resistant mortar is first shot against the shell. Then an outer shell of portland-cement concrete is added. The Lumnite section protects the ordinary concrete from heat and eventually serves as a refractory and corrosion-resistant lining when the original steel shell has disintegrated. By this method stacks are rebuilt while they are in use and there is no interruption of service.

Future Prospects and Developments

Before the war the use of refractory concrete was standard practice in many plants and industries. As it is essentially an economical material, those plants which have recently become acquainted with it under the pressure of war can be expected to continue its use in peace-time construction and maintenance. High production schedules and later reconversion of furnaces will doubtless lead to the building up of stocks of used firebrick which can best be salvaged and returned to work in the form of aggregate for refractory concrete. This will be an important item when production of consumer goods is again on a competitive basis.

In the technical development of refractory concrete much remains to be done. The manufacturers of calcium-aluminate cement are proceeding with an extensive research program and users of the product are investigating its possibilities in the solution of their particular refractory problems. The two main fields of exploration are the development of economical mixtures for high temperature service and the improvement of the strength characteristics in the range from 800 to 1500 F, *i.e.*, between the temperature where hydraulic strength is reduced and that at which ceramic bond is developed. Investigation of new aggregates is constantly under way. This is important because some materials which are not ordinarily thought of as refractories may be suitable for aggregate in refractory concrete.

From the construction standpoint the future of refractory concrete depends mainly on the ingenuity of engineers in adapting the principles of monolithic concrete construction to their requirements. Here again there is an analogy with the development of structural concrete in building construction. To develop efficient designs it is necessary to think in terms of concrete, to take advantage of the freedom of plastic design without neglecting the limitations of the material.

The construction of flat arches is an example of the possibilities for refractory concrete which have been only partially explored. The use of flat roof arches on industrial furnaces and kilns has been held back by the high cost of elaborate suspension systems. The rather obvious solution is to use flat slabs of refractory concrete. Several simple methods of reinforcing or suspending the slabs have been used or suggested. It is expected that the efficiency of flat arches in furnace operation will lead to standardized methods of construction with refractory concrete.

A Methods Article Spectacular results are being achieved in the use of induction heating for forging, especially with respect to surface condition, production output, uniformity and cleanliness. Mr. Strickland in this article (originally presented at the Induction and Dielectric Heating Conference in Chicago, January 17, 1945) discusses the engineering and operating pros and cons, including the economic factors involved, and gives some particularly interesting cost data for different types of induction heating equipment.

FIFTH IN A SERIES OF ARTICLES ON INDUCTION HEATING

Induction Heating for Forging

by **H. A. STRICKLAND, JR.** *Chief Engineer, Budd Induction Heating, Inc., Detroit*

NEITHER INDUCTION HEATING nor its application to the heating of metals for hot working and forging is new. The basic advantages inherent in its use for through heating are the same today as they were twenty years ago. If such is the case, then why should there be so much current interest in the application of induction heating to forging?

The answer to this question lies largely in the engineering and economic development of electric induction and related types of equipment. Today's prices are lower, largely because development of the necessary components of a high frequency system has recently progressed at a rapid rate. As the demand for equipment became evident, inductor type generators, high capacity power factor correcting capacitors (with ratings as high as 300 kva per can), co-axial cable, and better insulating materials became available. In no small way, this development has been assisted by the acceptance of induction surface hardening.

The trend toward large scale application of the induction method to forging heating has been particularly rapid during the war. The war created a tremendous demand for increased production of forgings of all types. Since induction heating is at its best in high production applications, it became the obvious selection for much of the new forging capacity of the nation. This trend toward induction heating has been accelerated both by the lack of a supply of skilled forging help *and* the opportunity for building new plants and installing new forging capacity without having to charge off existing facilities. In our own plant, induction heating for forging has made possible the forging of 25,000,000 precision forgings using manpower which has been recruited almost completely from men without any previous forging experience.

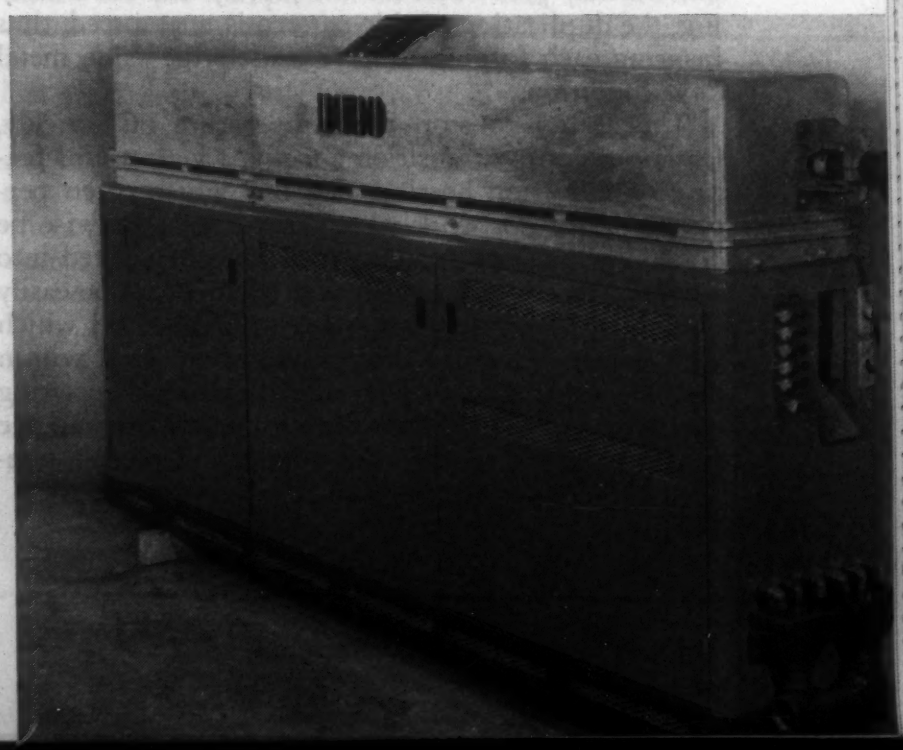
Some of the Advantages

There are many advantages in the use of induction heating for forging. One of the most important of these is the virtual elimination of all furnace-formed scale. Competitive methods of heating have scale losses of from 2 to 6% of the total weight of the heated piece. Loss data obtained in an engineering survey of a range of forgings shops have shown losses of approximately 4% in gas-fired furnaces, 6% in oil-fired furnaces and 2% in combination gas and oil-fired furnaces. Primarily, the elimination of scale eliminates the loss of a corresponding amount of metal. This is an important cost factor for with steel at 3c per lb., a 3% loss of material weight is worth nearly one cent on a 10-lb. forging. In addition, scale elimination benefits the forging operation through the elimination of a de-scaling operation which is frequently required in forge shops. Finally, the elimination of scale provides an increase in die life which has run in some instances as high as 300 to 400%.

A second major advantage in the application of induction heating to forging is the speed with which it is possible to bring metal to the forging temperature. In the induction method the heat is actually developed within the work-piece itself.

The bigger problem in rapid heating is to get heat into the bar rapidly rather than the problem of getting heat to flow from the outer metal of a bar or billet to the core. Typically rapid heating times by induction to forging temperatures of 2,300 F are eight seconds for a 1⅜-in. diam. bar, twenty seconds

Continuous induction heater for forging-billets.



for a 1¾-in. diam. bar, 110 seconds for a 3-in. diam. bar and seven minutes for a 5¼-in. diam. bar. The length of the work piece does not affect the rate at which it can be heated, inasmuch as no heat flow is required axially.

The third advantage is in the matter of space. Generally, the space required on the forging floor is less than one-third that required by fuel-fired furnaces.

A fourth advantage lies in the fact that no furnace warm-up period is required. Full production rate out of the heating equipment can be obtained immediately without a several hour delay waiting for furnaces to come to temperature. This advantage reflects itself in the elimination of the cost of delays, and the labor and fuel required in warming up conventional furnaces. In one case, a forge shop uses 4,400 gal. of fuel oil to operate a furnace on an eight-hour shift, but uses 1,800 gal., or over 40% of an eight hour supply, in order to bring the furnace up to operating temperature. In induction heating, little or no power need be used except when pieces are being heated. This fact together with the rapid heating of the process provides a flexibility of operation hitherto unknown.

Flexibility is particularly desirable from an operating standpoint for, in hot work, operations do not always proceed smoothly, and die troubles are frequently experienced. When heating with fuel-fired furnaces, if die trouble is encountered, it is necessary to hold the hot stock at forging temperature or to shut down the furnace until the trouble can be repaired. In both cases, excessive scaling of the stock is encountered, and, in the latter case, much heat energy is lost.

The practically immediate availability of one or two hot pieces of stock is another valuable feature of induction heating in setting up a job. When it is only necessary to have one or two pieces to make trial forgings, these pieces can be obtained without waiting but a few seconds which greatly speeds the necessary adjustments of the "setting up" process.

Uniform and Clean Heating

A fifth advantage is the uniformity of working temperature obtained with a simple control. This makes possible the production of better forgings with less skilled operators, as not only is the temperature of each piece uniform but the temperature pattern is also uniform. Whether a uniform or graduated heat pattern may prove best for the job, by induction heating, the duplication of this pattern is guaranteed, thus insuring each forging to have exactly the same metal flow conditions.

The ability to stop the temperature off quickly, leaving a narrow transition zone, is a very useful feature of induction heating, and one which often permits types of hot work which could not otherwise be done. For instance, a stud which is to be riveted into a hole so that it will swivel after cooling, can be easily assembled by heating only the end of the stud which is to be upset, leaving the portion of the stud within the hole cold. The cold metal will prevent upsetting of the stud inside the swiveling joint and back up the riveting operation. Another application of this phenomenon is in upsetting the ends of tubing, either internally or externally, forming a substantially square shoulder without the use of complicated dies to provide the shape. Here again cold metal is depended upon to resist the flow.

A further advantage reflecting itself directly in cost savings is the fact that, due to the more uniform heating results available with the induction method, it is possible to forge to closer tolerances and to throw less material into a flash. Forging flashes run from 12 to 30% of the weight of a forging and sometimes these may be reduced by two-thirds, the remaining flash being necessitated by the material allowance required for normal die wear. When the Budd Wheel Co. first entered the shell forging business, drawings called for forging weights as much as 39% higher than we found it necessary to employ, using induction heating. (See Table) At present we allow only 1/16 to 3/32 in. for machining on all but the largest shell forgings.

Another advantage, and one which promises to become more and more important with the passing of the years, is the fact that induction heating permits a clean and cool working area around the forging operation. The smooth simple surfaces of induction heating equipment are also easy to keep clean. Not only do these ideal conditions bring a forging shop substantially into the same type of business as a machine shop, but they appeal to workers and permit much higher outputs during the hot months of the year when forging shops rarely run at maximum rates.

Table of Typical Forging Weights
vs.
Induction Heating Production Weights

Shell	Govt. dwg., wt., lb.	Budd Wheel Co. avg. prod. wt., lb.	Ratio
60 mm.	3.33	2.39	0.72
81 mm.	6.88	6.00	0.87
90 mm.	30.00	24.40	0.81
105 mm.	40.50	33.87	0.83

Production per man can often be increased many times. At one particular company, a piece forged on an upsetter and heated with an oil-fired furnace required a crew of four men to obtain a production of 85 pieces per hour. After the job was set up for induction heating, it was possible to secure a production of 190 pieces per hour with a crew of two men.

Selection of Power Equipment

There are three basic types of high frequency generators which are used for induction heating. These are:

1. Motor generator sets.
2. Vacuum tube oscillators.
3. Spark gap oscillators.

When materials are handled in any volume, as is usually the case in hot work, both the spark gap oscillator and the vacuum tube oscillator are generally far too expensive in both first cost and in operation for application. Cheapest available vacuum tube oscillators have an approximate cost of $160 per kw. (At 1650 kw. small oscillators run approximately from

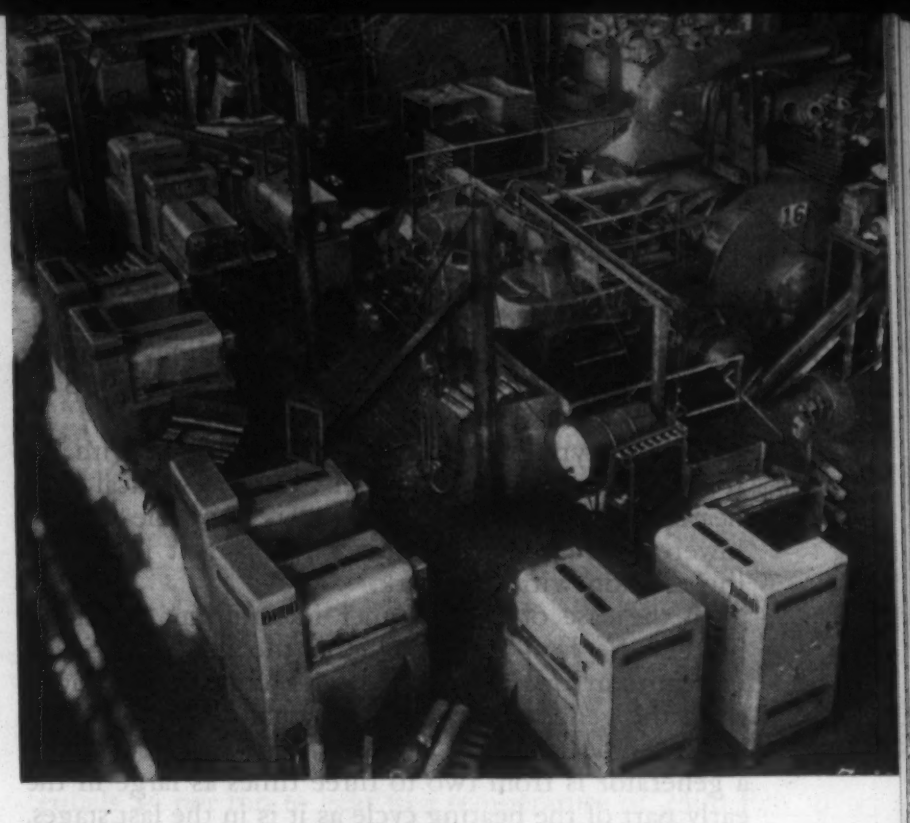
two to three times this value.) Cheapest spark gap oscillators, which are also limited in power output to a value too low for most forging, have a comparable cost. By far the least expensive source of high frequency energy is the motor generator set which can be obtained in 3,000 cycles rating for $52 per kw. including motor starter and controls equipment. The cost of 960 cycle equipment is slightly less while the cost of 9600 cycle equipment is somewhat more. Even if the first cost of oscillators was competitive with generators, the operating cost would be excessive. Overall efficiency of oscillators is approximately 50 to 55% even in the largest sizes, while motor generator sets have efficiencies up to 88% and are rarely less than 80%.

For each frequency there is a minimum diameter of steel which can economically be heated to forging temperature. With 960 cycles it is uneconomic to heat bars smaller than 2¼ in. in diam. With 3,000 cycles it is uneconomic to heat bars less than 1¼ in. in diam. With 9,600 cycles it is uneconomic to heat bars less than 11/16 in. in diam. When it is necessary to heat diameters smaller than 11/16 in., it becomes necessary to consider one of the oscillator types of power sources. While 20,000 cycle generators are under development, their current costs are in the neighborhood of oscillator prices.

From the above cost and size limitations, it would seem that to heat diameters larger than 2¼ in. in steel, it would be most desirable to use a 960 cycle generator. However, the cost of power factor correction capacitors at 960 cycles per second is more than double that at 3,000 cycles. Therefore, the cost advantage, even for larger diameters in using 960 cycle generators, is not as marked as generator figures alone indicate. A heating current of 960 cycles per second will provide slightly more rapid heating of larger bars due to the fact that the current flow actually penetrates into the work about 70% deeper than in the case of a 3,000-cycle heating current.

This advantage is offset, however, by the ability of 3,000 cycles to heat a larger range of bar size and if such a thing as a tentative standard may be suggested, it might seem that 3,000 cycles would be the logical selection for that honor. The need for equipment to handle diameters which can only be handled by 9600 cycles and the occasional advantage of 960 cycles particularly in shops dealing only in large diameters has secured for them a place in the forging field. As a matter of fact most heating equipment designs are arranged to use frequencies from 960 cycles to 9600 cycles with no change other than in the capacitors used.

With respect to heating of non-ferrous materials—that is, aluminum, brass, copper and their alloys—due to their higher conductivity the actual electrical efficiency of heating them is less than in the heating of steel. In every case, with the same frequency, smaller diameters of non-ferrous materials than of steel can be heated. The energy requirements for heating non-ferrous alloys, in spite of the fact that the so-called electrical efficiency is lower than with steel, is, however, not particularly high. It is interesting to note that the power requirements to reach a hot work temperature with the common non-ferrous metals are about the same or less than that required by steel.



View in a shell-forging shop, showing layout of induction heaters.

Aluminum, for instance, though an excellent electrical conductor, can be heated to its forging temperature with about the same investment and operating costs per pound as required by steel in heating to its forging temperature. The lower forging temperature to which it is necessary to heat aluminum offsets both a higher specific heat and lower electrical efficiency. Advantages of heating aluminum by induction are particularly notable because of the short heating time factor. Aluminum heating in conventional furnace equipment takes as long as two hours to bring a 5-in. diam. piece to its forging temperature. The same piece can be uniformly heated to a forging temperature of 850 F by the induction method in two minutes. This tremendous increase in heating speed cuts the floor space requirements drastically. The advantages in heating brasses and copper are, in both cases, in the speed of heating and the elimination of scale, and, in heating brasses, the complete absence of de-zincification.

Heating Machines and Equipment

Two basic types of machines are used in heating for forging. One is the bar heater in which a bar or piece to be heated is inserted into the heating coil through the front of the machine. A button is pressed and the heating cycle is carried out automatically from there. At the completion of the heat, the piece is withdrawn from the coil and hot work may proceed. In this type of heater, it is possible to heat a complete bar or, if desired, only the end of the bar, for operations such as upsetting, flanging and so forth. In heating the entire length of a bar, it is necessary to insert the workpiece completely within the coil. A foot-operated push out mechanism is provided to push the heated bar far enough out of the heater to permit the application of work handling tongs.

Where complete heating is permissible, as in billets, it is more efficient and usually requires less investment to use a continuous type of heater. In the continuous billet heater, stock is fed by a chute, hopper, or conveyor to a pusher mechanism which pushes

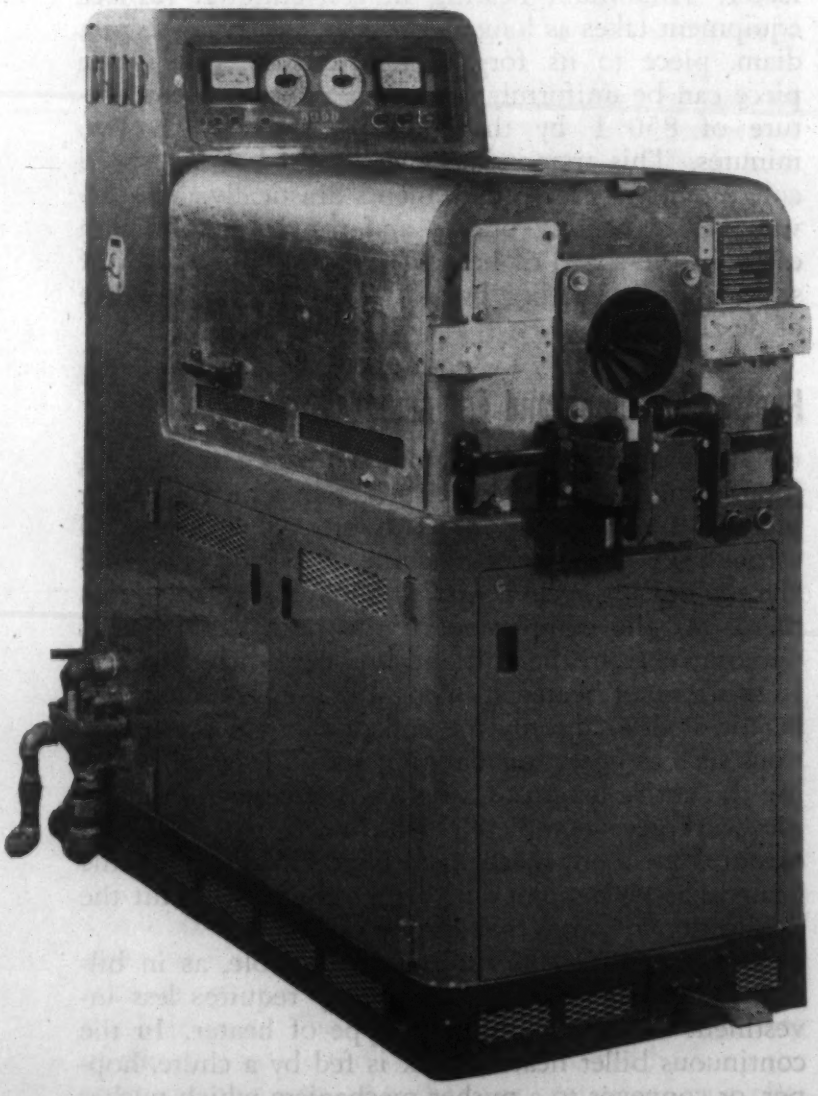
billets through the heating coil or coils until they drop out the delivery end at working temperature. Costs are generally lower than with bar heaters because radiant heat losses are less and generator loadings are more uniform. Single units of this type handling up to 9,000 lb. of steel per hour are available.

A third type of heater is sometimes used with extremely large masses of steel. It is a vertical type heater where the heating coil is movable and is lowered around the workpiece to bring it into heating relation with the work.

In the case of bar or other intermittent operation heaters the load imposed upon the generator is an intermittent one since the heater only draws power from the generator when it is actually heating. Also, when the heating load is steel, the power drawn from a generator is from two to three times as large in the early part of the heating cycle as it is in the last stages. Due to these factors, a wide variation in load on the generator will be encountered if no means are taken to start or dispatch the heaters so that a more uniform load will be drawn. To this end a sequence controller is employed which actually starts the heating. However, it is necessary for the heater to be properly loaded and the starting button pressed before the sequence controller can start the heating operation. After starting, the sequence controller has no further control over the heating cycle, as timers in the individual heaters serve to control duration of heat.

Coil construction as used in Budd induction heaters consists of a closely spaced winding of specially drawn copper tubing, completely insulated electrically, and made self-supporting by a surrounding insulation tube. The electrical space factor is high, in the neighborhood of 95%, which is an important factor in maintaining high electrical efficiency. Water-cooled alloy steel work supporting rails are placed inside the coils. These rails have projecting slugs which support the workpiece and are spaced equally around the interior of the coil. Between the slugs small retainers are located which serve to hold in place refractory brick segments which are slid between the rails.

This assembly provides a highly wear resistant production tool which has in individual instances heated more than 250,000 pieces without service. When abrasion conditions are particularly bad, the work supporting slugs are hard faced with an even more wear resistant material. This coil construction is used both in bar heaters and in the continuous billet heaters where several coils may be placed in series to provide heating zones.



Bar induction heater.

Applicability of Induction Heating

In deciding upon the applicability of induction heating to a job, it is necessary to consider the length of the production run. Inasmuch as induction heating coils are designed to do specific jobs, it is usually necessary to change coils when changing from one job to another. If a length of heating run is particularly short, a high proportion of time will be spent in changing coils. How short a run it can be economically used on is as yet undetermined, but in all probability, if the need develops, coil mounting devices which permit even quicker interchangeability will be developed to reduce setup time. It is desirable, wherever possible, to design heating coils to do two or more pieces since such a policy cuts down the number of coils required and eliminates change-overs.

Another possibility for use in shops where stock size is not varied over too great a range is to employ a heating coil large enough to accept the biggest work piece. Smaller pieces can then be inserted in the coil and heated, though heating time may not always be in the desired range. Heating of a small bar in a larger coil than necessary is done at some expense of efficiency. However, in the case of heating steel to forging temperatures, this reduction in efficiency is not great over a stock diameter range of 2 to 1. In our own plant, we have had one heater set up for more than a year with a single coil in it. Perhaps over a hundred different types of pieces have been heated in this coil for experimental forging. Such an arrangement is induction heating's most flexible form.

One induction heating application to approach carefully is the practice of forging off the end of a bar. Inasmuch as, in this practice, forgings are made off the hot end of a bar and sheared off, there is some remaining heat in the bar end. As the induction heating process adds a predetermined pattern of heat, re-insertion of a bar with a hot end in the heating coil would result in melting the hot end of the bar. It is therefore, necessary to cool the ends of the bars before re-insertion in the heating coil in order to prevent melting of the bar. Where it is desired to apply induction heating to such a job and provision for cool-

ing is not desirable, it is recommended that consideration be given to cold shearing into billet lengths and then heat automatically through a continuous billet heater. The hot work pieces can be delivered by this type of machine literally under the operator's nose.

Another method of handling such pieces is to heat, in a bar heater, a piece long enough to make three or four forgings, and hot shearing the bar at the work station, doing all the forging from that bar with a single heat.

Generally speaking, people think of induction heating as being applicable only to symmetrical pieces of uniform section, such as bars, tubes, and billets. It is not so well known that sections non-uniform along their length can be heated to a uniform temperature. In other words, it is possible to heat to uniform work temperature a bar with an enlarged section or a tube with a thicker or thinner wall along its axis. A variable tubing wall thickness around its circumference is undesirable in heating to a uniform temperature.

Some Cost Considerations

To most people, the only drawback to induction heating is its first cost. Forging heating by induction, where applied to bars 1¼ in. in diam. and larger, currently requires an investment of approximately $17 for each pound heated per hour. In other words, an installation to heat 3,000 lb. per hour would cost approximately $50,000 for complete generating equipment (including motor starter and generator control) and heating equipment. This cost is admittedly higher than that required for the purchase of gas or oil-fired furnaces with the same nominal rating. However, the difference is not as great as it might seem at first. Most fuel-fired furnaces require storage facilities for fuel on the premises. In the case of oil or butane gas, there is the handling from tank cars to the storage facilities.

In the case of oil-fired furnaces there is pre-heat equipment for the oil. Both oil and gas equipments require piping facilities to the individual furnace, and if any semblance of temperature control is to be obtained at the furnace, additional temperature control equipment is required. This investment for an installation heating 3,000 lb. per hour is, from one case on record, $16,525 which is $5.50 per lb. per hour. (Home-made furnaces have lower figures than this but operate at poorer efficiencies.) This figure is for the same furnace which was employed in the example previously mentioned where a change to induction heating more than doubled production and used at the same time only one-half the previous crew. In this case, both the induction and oil-fired heating units were rated at 3,000 lb. per hour. However, it appears that the utilization factor in the induction equipment is much greater, inasmuch as the reason given for low production with the fuel-fired furnace was that it was not big enough for the job.

A difference in first cost can be and is, with properly installed induction heating equipment, offset by savings in operating costs which will be brought out later.

It is usually impossible to re-insert a forging for re-heating after it has been partially forged or its original shape destroyed. To take care of scrap salvage, it is customary in induction heated forging shops to use a small portable gas or oil-heated furnace which can be moved from one forging location to another periodically to clear up any scrap which may be accumulated.

A large portion of the cost of induction heating is due to the cost of the generating equipment which runs with 960 to 3000 cycle generating equipment (including motor starter and generator control) from $50 to $55 per kw. In bar heaters the cost is approximately $35 per kw. while the continuous type of billet heater has a cost as low as $22 per k.w. One kilowatt of high frequency capacity will heat about 6 lb. of steel per hour.

As far as direct comparison of current costs versus fuel costs, the current cost is generally higher, 60 cycle motor power being drawn at a rate of 400 k.w.h. per ton, which with current at one cent per k.w.h. equals $4 per ton to heat to a temperature of 2300 F. Fuel-fired furnaces are reported as running 43.8 lb. per gal. of oil to a temperature of 2150 F which with oil at 5c per gal. equals $2.30 per ton, a difference of $1.70 per ton in favor of oil. However, a 2% scale loss amounts to 40 lb. of steel for every ton heated while 6% scale loss amounts to 120 lb. for every ton heated. With steel at 2½c per lb. this saving alone is worth from $1 to $3 per ton and proportionately more with higher cost steels. In addition, it is necessary to provide warm up oil for the furnaces.

Die life improvement due to scale elimination, plus savings in the amount of stock required to make the piece due to closer tolerances and more uniform forging conditions, plus the reduction in the weight of material heated due to stock reduction and sharper temperature transition zones, are factors impossible to evaluate on a pound basis but which offer large direct cost savings usually much larger than the scale savings listed above.

Conclusions

In conclusion, while the investment cost of induction heating is greater than fuel-fired equipment, it offers operating costs which are, in many cases, considerably lower than those of previous methods. In addition to tangible cost savings, the application of induction heating offers many intangible advantages which are hard to evaluate in dollars and cents but which in the long run will undoubtedly make their weight felt. These consist in the improvement in working conditions in forging shops commensurate with the improvement of working conditions in machine shops which accompanied the elimination of overhead line shafting, belt drives, and poor illumination which today have largely been superseded by the clean, light, modern shop with its individual motor drives on all machine tools.

The field of induction heating is especially that of high production, and, in combination with upsetters and forging presses, tremendous quantities (600 pcs. per hr.) of medium size forgings per hour can be produced at a single station. We firmly believe, that any company contemplating the conversion or extension of existing forging shop facilities or the planning of new installations would be doing themselves an injustice if a thorough study of electric induction methods were not made and comparisons drawn between them and gas or oil-fired installations.

Post-Formed Laminated Phenolic Plastics —An Addendum

by **FRANK SULLIVAN** *Engineering Department, The Formica Insulation Co., Cincinnati, Ohio*

Through an editorial error, a portion of Mr. Sullivan's article in our February issue was omitted. The missing material, containing much useful and specific information on the working behavior and physical properties of this new form of plastics, is presented below, with our apologies to Mr. Sullivan and to all our readers.

—The Editors

Heating and Shaping Methods

Several types of heating equipment are satisfactory for forming. Circulating and non-circulating hot air ovens, molten alloy and salt baths, radiant heat ovens, and contact with a hot plate all have been used successfully. The temperature and heating time must be adjusted to reach optimum conditions for each time the heat transfer from each medium varies. For sheet stock of 1/16 in. thickness time periods given in this table have been observed:

Heating Method	*Temperature, °F*	*Heating Time, Sec.*
Circulating hot air oven	500	45
Non-circulating hot air oven	500	52
Non-circulating hot air oven	435	60
Oil bath	355	32
Molten low-melting alloy	355	30
Molten low-melting alloy	435	21
Contact with hot plate	435	36

Identical formed pieces have been produced by all the above methods and the selection of one in preference to another will depend upon the facilities of the manufacturer. Perhaps the hot bath of oil or low-melting alloy gives the most uniform conditions but some cleaning of the part must be done since in the latter case particles of metal will cling to the edges of the piece, while in the case of oil degreasing is necessary. Contact with a hot plate is never very uniform and this will lead to a high percent of waste through blistering and cracking. Hot air ovens are slower in operation and harder to maintain at uniform conditions but for larger pieces of material they are usually most convenient.

The radius to which the laminated stock (CNP-11) may be bent may be found by substituting the following formula, where R is the radius and T the thickness in inches: $R = 6(T\text{-}3/64)$. This material in 1/16 in. sheet has also been drawn to a depth of 1½ in. for a 3 in. diameter cup.

In some cases forming stock can be formed in jigs or molds that have been made for forming aluminum or sheet metal, but usually this is not possible. Most formed articles to date have required only simple bending of the material and for this all that is necessary is to clamp the material and bend it to shape with a hinged section. Handles of various kinds will supply the leverage necessary and simple fastening devices will hold it in place. In many instances wood male and female dies can be used and usually these can be band sawed and sanded to the required dimensions. For more intricate forming guides, pins, and holding devices will be needed to insure exact placement in the form.

Drawing operations are somewhat similar to those used in drawing metal in that a hold-down plate and a positive means of controlled pressure are needed. Hard wood is usually sufficient for the drawing form unless several thousand pieces are needed and then it is usually advisable to construct them of metal. Plastic materials, plastic-impregnated wood, and composition materials may also be used in the construction of forming and drawing tools. The pressure needed to form a part will depend to a great extent upon the size, thickness of material, and the type of forming operation.

For simple bending hand pressure is sufficient, while for drawing large, thick sheet material, air arbor presses, or hydraulically operated presses will be necessary. If forming tools made of metal are used, these may be water cooled, if necessary. When using wood, plastic, or composition forms, it is common practice to resort to no forced cooling, but to provide enough forms so that 3 to 5 min. may elapse from the time of closing the form to the removal of the formed product.

In many cases it is possible to form a piece and in about 30 sec. remove it from the form and transfer it to a cooling frame. If a short time is allowed for the form to cool before loading again, there is rarely a condition of overheating. This procedure may be hastened by directing a stream of air over the form.

The Formed Part

The physical properties of the material used for post-forming are given below:

Flexural Strength	19,500 p.s.i.
Tensile Strength	9,900 p.s.i.
Compressed Strength	31,000 p.s.i.
Izod Impact—Side	2.6
—Face	4.7
Water Absorption—1/16 in. for 24 hrs.	1.7%
Dielectric Strength, Step-by-Step	110 volts per mil
Power Factor	6.3

MATERIALS & METHODS MANUAL

4

This is another in a series of Manuals on engineering materials and production methods, published at periodic intervals as special sections in Metals and Alloys. Each of them is intended to be a compressed handbook on its particular subject and to be packed with useful reference data on the characteristics of certain materials or metal-forms or with essential principles, best procedures and operating data for performing specific metal-working processes.

Materials for High-Temperature Service

by Oscar E. Harder, Assistant Director

Battelle Memorial Institute, Columbus, Ohio

From gas turbines and steam power plants to heat treating furnaces, operating temperatures are going higher and higher, imposing increasingly severe requirements on the materials to be used in their construction. The selection of heat resisting alloys is therefore one of the most important problems faced by engineers today, and also one of the most difficult. This Manual is intended to serve as a guide in selecting the right materials for applications at temperatures above 1000 F by outlining the most common high-temperature service problems and describing the types and characteristics of the various cast and wrought heat-resisting alloys available for these specific applications. It can be heartily recommended as a concise and fact-full review of the entire field of high-temperature materials engineering.

Contents

Introduction . . . . . Page 726
Requirements and Testing . . . . . Page 726
Heat-Resistant Alloy Castings . . . . . Page 727
Wrought Alloys . . . . . Page 729
Very Recent Developments . . . . . Page 733
General List of Alloys . . . . . Page 736

Metals and Alloys, March 1945

Introduction

IT IS PROBABLE that a thousand alloy compositions have been studied for high-temperature service, and a few hundred compositions have been used or are being used at the present time. For illustration, a recent publication on exhaust valve steel listed over 30 alloys. In the seamless tubing industry, at least 50 compositions have been used for piercing points, plugs, and guides. One company interested in turbosuperchargers has studied over 30 compositions, and the various Government agencies have studied about 100 alloy compositions for high-temperature service. Thus, if we consider the many fields involving high-temperature applications for metals and alloys, we find a large number of materials.

The alloys which are of most importance have as base materials the closely related metals in the periodic table, iron, nickel, and cobalt. Chromium has a major role in all of these alloys and is the metal of greatest importance in conferring resistance to oxidation to the various base metals. The base metals, nickel, iron, and cobalt, have been used individually with chromium as in the nickel-chromium resistor elements; iron with chromium as in the chromium steels and irons; cobalt and chromium as in Stellite and Vitallium; or as combinations of two or all three of these base metals with chromium. As special modifying elements for these more basic compositions, most of the metals in the periodic table have been considered, and there are definite uses of molybdenum, tungsten, silicon, aluminum, vanadium, columbium, calcium, zirconium, titanium, and tantalum, either used alone or in combination. Doubtless a number of other metals have been used, and numerous other metals have been disclosed and claimed in patents.

In the case of the noble metals for use at elevated temperatures, the picture is somewhat less complicated, but platinum is used as the pure metal and as an alloy with one or more of the metals of the platinum group, but more particularly with rhodium and iridium, and it is also now being used alloyed with about 4% W for spark plug electrodes[1]. An alloy of platinum and molybdenum (4% Mo) has been patented for spark plug electrodes[2], and an alloy of platinum and nickel (0.25 to 2.0% Ni) for high-temperature service[3].

The story of the early work on the nickel-chromium alloys is of interest because of the development of that type of alloy and its relation to many other developments. It is now 40 yr. since Albert L. Marsh filed his patent application, "Thermoelectric Element," which was issued in 1905 as U. S. No. 781,288. This development was directed more particularly to an alloy for thermocouples and was the beginning of the now extensively used base metal thermocouple known as Chromel-Alumel. It was while studying this same type of alloy that he discovered its high electrical resistance, and in 1905 he filed a patent application which issued as U. S. No. 811,895 in 1906, "Electric Resistance Element." This development was the forerunner of the heat-resistant alloys containing about 80% Ni and 20% Cr, now extensively used as electrical resistors. It has been modified only slightly to develop an alloy which is also used for facing on exhaust valves for aircraft engines.

From this base analysis, other electrical resistance alloys and many other heat-resistant alloys have been developed. For example, rather early there was use of an alloy containing about 60% Ni, about 15% Cr, and the balance iron, which essentially results from diluting the 80-20 alloy by the addition of about 25% Fe. However, originally iron was introduced to overcome manufacturing difficulties. This type of alloy was also used as a cast heat-resistant alloy, and many other alloys resulted from this type of modification in which the nickel was reduced to 30 to 40%, with 15 to 20% Cr, and then further by reduction of the nickel to 10 to 15% with the chromium increased slightly to produce alloys containing, roughly, 12% Ni and 25% Cr. These latter alloys will be discussed more in detail under the heading of "Heat-Resistant Alloy Castings."

Requirements and Testing

Before going further with this discussion, some attention may be given to the requirements of metals and alloys for service at elevated temperatures and testing methods. Among the most important is strength at high temperatures. Ferritic alloys, for example, usually have low strength at elevated temperatures. Fig. 1 shows three common arrangements of the atoms or crystal lattices of metals and alloys. These are described as face-centered cubic (austenitic), body-centered cubic (ferritic), and hexagonal. The last is illustrated by such metals as magnesium and zinc. Considering the austenitic and ferritic types, it is found that the former has a more dense packing, and its range of stability is generally at the higher temperatures. These relations are considered to account largely for the better strength of austenitic alloys at elevated temperatures.

Resistance to oxidation and (sometimes) high electrical resistance are other important requirements. Corrosion in its various forms must be considered, and testing methods must simulate those conditions. For example, exhaust valve alloys and spark plug electrodes must resist corrosion attack by the products of combustion of the fuel, and the effect of the ethyl fluid is quite important[9]. Laboratory tests have been developed for this purpose, and correlations with service performance have been worked out. Other corrosion problems are encountered in fuel-fired furnaces, especially when high-sulfur content fuels are involved and there are various degrees of combustion. For example, high-nickel alloys are more seriously attacked by high-sulfur fuels under reducing conditions. Fused salts and molten metals present still additional corrosion problems.

Mechanical Properties

Some alloys become embrittled in service, particularly at certain temperatures, and embrittlement must be held to a usable limit. For example, certain combinations of iron and chromium form an intermetallic compound, particularly at temperatures in the range of 1200 to 1600 F, a relation which will be discussed more in detail later. Embrittling tendencies can be tested by aging the alloys and then determining the ductility. Whole installations have been built of alloys which had not been tested and were later found to embrittle at service temperatures so that the whole equipment had to be scrapped.

Perhaps the most important mechanical properties for high-temperature service are those grouped under the general heading of load-carrying capacity. If long-time service is contemplated, creep tests are usually made. Such tests are expensive and time consuming because little value can be attached to a test which runs less than 1,000 hr. The results of such tests are usually expressed as limiting creep stresses (L.C.S.), which generally means the maximum load the material will sustain at a given temperature with a minimum rate of deformation of 1% in 10,000 hr. In some of the less critical applications, the value is 10% in 10,000 hr., but in some applications the value is 1% in 100,000 hr.

Fig. 2 shows creep curves for two heat-resistant alloys of the 25% Cr, 12% Ni type. Alloy AS-2 is wholly austenitic, with a ratio factor (discussed later) of 1.54, while Alloy AX-1 is rather strongly ferritic, with a ratio factor of 1.87. The creep tests were at the same load (2,000 p.s.i.) and at the same temperature (1800 F), yet the final rate of creep was about 12 times as great on the partially ferritic alloy as on the wholly austenitic alloy. Both of these alloys meet A.S.T.M. chemical specifications[7] and illustrate the importance of microstructure in relation to properties.

For applications in which weight reduction is highly important, a shorter life may have to be anticipated, and for this type of application, stress-rupture tests are used extensively. This test involves loading the specimen at a stress which will cause rupture and then determining the time required for failure. Usually, about three well-chosen loads will give sufficient data to estimate the load which the material will carry without failure for a selected period of time. In some extreme cases, life of 100 hr. has been considered acceptable, or, stated another way, design engineers reduce weight to that extent with the materials available. More generally, however, stress-rupture data are used as quick approximations of behavior, and designs are then estimated or guessed at to hold deformation to permissible limits. This type of testing has gained favor, as compared with short-time tension tests and long-time creep tests, during the past few years.

Short-time tension tests at elevated temperatures are used and give supplementary information but are not necessarily a reliable criterion for the other properties just mentioned.

Hot hardness tests give valuable information regarding the high-temperature prop-

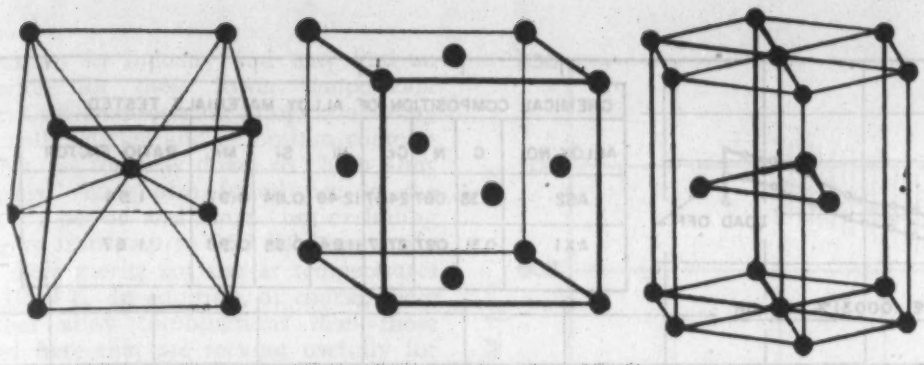


Fig. 1. Crystal lattices common in metals and alloys. Left to right, body-centered cubic, face-centered cubic, and hexagonal.

erties of alloys and may be used for first approximations. A few years ago it was shown that there was a relatively close correlation between the hot hardness at about 1100 F and the cutting efficiencies of high speed steels and other cutting-tool materials.[8] Fig. 3 shows the simple equipment used for this test, and Fig. 4 shows the relation of testing temperature to hardness for a family of high speed tool steels. Stellite, Carboloy and other cemented carbides have hardnesses at 1100 to 1200 F that are higher than those of the high speed steels and they likewise show longer tool lives under severe machining operations.

Heat-Resistant Alloy Castings

The relative production of heat-resistant alloys over the period of 1935 to 1940 is shown in Fig. 5. The total production in 1943 showed an increase of nearly 600% over 1938 and of over 400% above the average for 1934 to 1940. The "HW" alloy of 60% Ni had been practically discontinued. The "HT" and "HH" alloys each represented 37.5% of the total. (The Alloy Casting Institute designates the 25 Cr - 12 Ni, 35 Ni - 15 Cr, and 60 Ni - 12% Cr alloys as "HH," "HT," and "HW," respectively.)

High-Nickel Alloys

Early in the development of cast heat-resistant alloys of the type used in heat-treating furnaces and many other applications requiring similar service came alloys of about 60% Ni, 15% Cr, and 25% Fe.[5] They were in many respects simply an adaptation of the electric resistor alloy but with higher carbon contents and generally higher silicon and manganese contents to improve castability. This type of alloy was extensively used for carburizing boxes and furnace parts and is still recommended for applications which involve resistance to carburizing and to thermal shock. The use of alloys of this type has been largely eliminated by Government regulations during the war because of the scarcity of nickel. The production at the present time is a very low percentage of the cast heat-resistant alloys.

Somewhat later there was further reduction in the nickel content of the cast heat-resistant alloys, and then extensive production of alloys containing 35 to 40% Ni with 15 to 20% Cr, frequently referred to as the 35-15 alloy. This type of alloy tended to replace the higher nickel alloys and represented the largest tonnage production up to about 1936, at which time the 25% Cr - 12% Ni alloy became the largest tonnage production material. During the past 2 yr., there has been some increase in the production of the 35-15 type because of the practical elimination of the 60-15 type alloy and the use of the 35-15 type in the applications where the higher nickel alloy had previously been used.

High-Chromium Alloys

The high-nickel alloys of the 60-15 and the 35-15 types are inferior to the higher chromium alloys, such as 25 Cr - 12 Ni, in resistance to sulfur-containing gases, particularly under reducing conditions. The high-nickel alloys are subject to sulfur attack, and it is important to use higher chromium contents when the atmospheres are high in sulfur, particularly if reducing conditions are encountered.

The 25 Cr - 12 Ni alloy is a more recent development and, for a considerable period of time, was looked upon as a cheaper and inferior alloy. This resulted, in part, from a lack of understanding of the alloy and from the production of alloys of compositions within the usual chemical specification limit but which were highly ferritic and subject to the formation of the brittle intermetallic compound of iron and chromium (FeCr) in certain temperature ranges, and at the higher temperatures were ferritic and of low strength.

The iron-chromium diagram as proposed by Kinzel and Crafts[12] is shown in Fig. 6. The intermetallic compound is indicated to occur in alloys containing chromium between about 30% and about 63% at ordinary temperatures and in alloys of about equal iron and chromium contents to form at a temperature of about 800 C (1472 F). This intermetallic compound is not indicated to exist at higher temperatures. This same intermetallic compound has been found in heat-resistant alloys of the 25 Cr, 12 Ni type. A study of this type of alloy for the Alloy Casting Institute[13] disclosed that the intermetallic compound occurred only in certain alloys, particularly those high in chromium relative to their nickel and carbon contents. It was found that this relation could be indicated by a ratio factor which is given by the expression [Cr minus (16 x C)] divided by the nickel.

It was also found that, for this type of alloy, if the ratio factor was below about 1.7, the alloys were wholly austenitic, but if above this value, the amount of ferrite increased as the ratio factor increased. Thus the chromium is in its usual role of ferrite promoter, while carbon and nickel are austenite-promoting elements. These relations have been reduced to a nomographic chart which is shown in Fig. 7. For a given carbon content, this graph is drawn to show the maximum and minimum chromium and nickel contents respectively.

Working with balanced alloys which are wholly austenitic, it was shown that certain relations could be established between the carbon and the nitrogen contents and such mechanical properties as yield strength, elongation, and tensile strength. Tests have been made at room temperature on aged specimens, to show the relation of yield strength to the carbon and nitrogen content. It is evident from these tests that nitrogen is twice as potent in increasing the yield strength as is carbon. Other tests on the elongation in relation to the carbon and nitrogen contents of the same group of alloys show, similarly, that nitrogen is only one-half as harmful in reducing the elongation as is carbon.

From the data obtained in these tests the nomographic chart of Fig. 8 was derived. This correlates nitrogen and carbon contents with yield strength and elongation of these balanced austenitic alloys at room tempera-

Table I. Comparison of Creep Rates of Wholly Austenitic and Partially Ferritic Alloys at 1800 F Under a Load of 2,000 p.s.i.

Alloy No.	*Microstructure*	*Min. Creep Rate, % per Hr. x 1,000*	
AD	Austenitic	0.045	
AE	Austenitic	0.035	
AS-1	Austenitic	0.030	
AS-2	Austenitic	0.025	
AS-4	Austenitic	0.020	
AU-2	Austenitic	0.020	
AS-53	Austenitic	0.010	
AQ	Austenitic	0.010	
AQ-2	Austenitic	0.010	Aver. 0.023
AX-1	Partially ferritic	0.220	
AS-5	Partially ferritic	0.230	
AT-2	Partially ferritic	0.100	
AN-2	Partially ferritic	0.667	Aver. 0.304

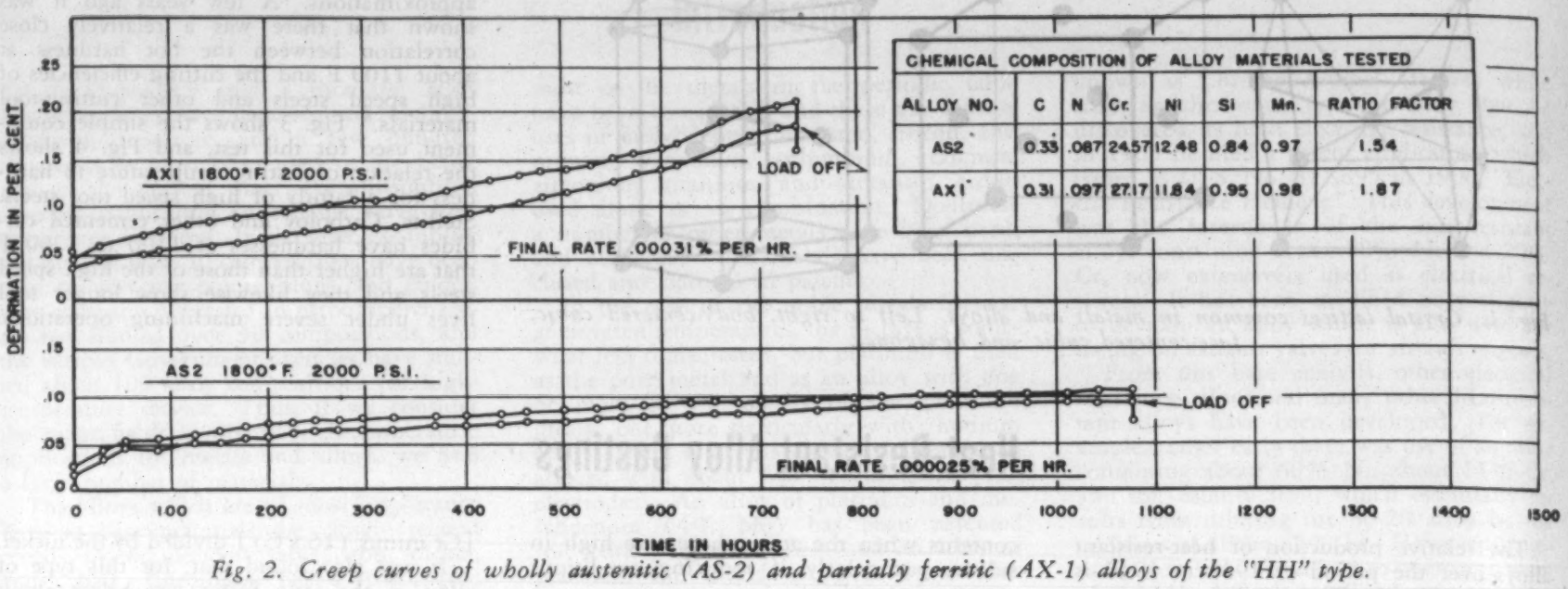


Fig. 2. Creep curves of wholly austenitic (AS-2) and partially ferritic (AX-1) alloys of the "HH" type.

ture. From a similar series of tests at 1600 and higher, nomographic charts were developed for the strength and ductility properties of the alloys as a function of carbon and nitrogen contents at elevated temperatures, and the relations at 1600 F. are shown in Fig. 9.

The same alloys were subjected to creep tests at various temperatures, and the alloy numbers, the microstructures, and the minimum creep rates are given in Table I. The first nine alloys are wholly austenitic, while the next four range from slightly to rather strongly ferritic. It will be noted that the average minimum creep rate for the four partially ferritic alloys is more than 10 times the average minimum creep rate for the nine alloys which are wholly austenitic.

An Emergency Heat-Resistant Alloy

At the request of the Alloy Casting Institute, Battelle undertook to develop an emergency alloy which would be relatively low in the scarce metals, nickel and chromium[14]. After studying about 100 alloy compositions, an alloy was developed for use at temperatures up to 1400 F, containing about 10 to 12% Cr, about 2% Si, with nickel in the range of 4 to 10% and manganese in the range of 2 to 12%, with the nickel and manganese supplementing each other to give a wholly austenitic alloy. This alloy makes it possible materially to decrease the chromium, and by using manganese to replace the nickel, the amount of nickel also is greatly reduced. Fig. 10 illustrates the way in which the manganese and nickel must be used in order to produce a wholly austenitic alloy.

An unusual finding was that as the chromium content decreased for any nickel level, the amount of manganese had to be increased. This was contrary to the findings for alloys of the 25 Cr - 12 Ni type. In this alloy, as in the 25-12 type, it is essential that it be wholly austenitic for good creep resistance, and if the nickel or the manganese is below the minimum indicated by Fig. 10 the alloy becomes ferritic, and only a relatively slight departure from the wholly austenitic alloy may reduce the load-carrying capacity by as much as 50%.

Creep curves for two alloys studied in this campaign are shown in Fig. 11 along with an 18-8 alloy discussed earlier. Alloy FH-2, according to the curves in Fig. 10, with 10% Cr and 8% Ni should contain a minimum of about 6.5% Mn but contains only 5.0% and, consequently, is partially ferritic. Alloy GK, on the other hand, has more than the necessary amounts of nickel and manganese to make it stably austenitic. These differences in structures are reflected in their load-carrying capacities at 1600 F. The partially ferritic alloy (FH-2), under a load of only 2,000 p.s.i., showed a minimum rate of 0.00017% per hr., but in less than 600 hr. entered the third stage of creep with a final rate of 0.00042% per hr. The stably austenitic alloy (GK), under a 50% greater load (3,000 p.s.i.), showed a lower minimum rate (0.000115% per hr.) and showed no trend for the rate to increase in 800 hr. under load.

Fortunately, the nickel and chromium situation has not become so serious as it was feared it might be, and it has not been necessary to resort to the use of this emergency alloy. However, it is being used to

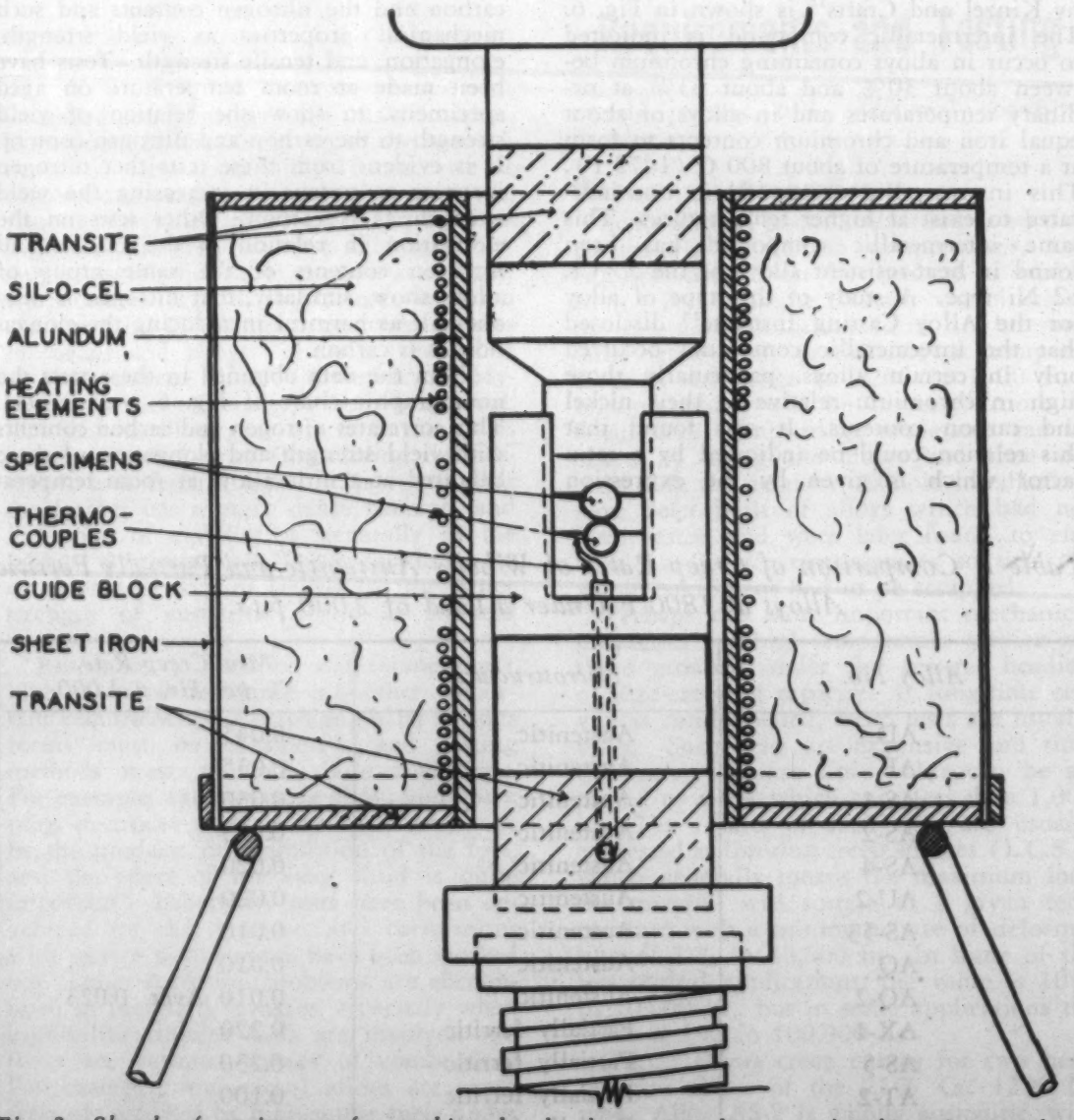


Fig. 3. Sketch of equipment for making hot-hardness tests by mutual-indentation method.

some extent in industry and may find an application for these lower temperature ranges. Cast heat-resistant alloys containing even smaller nickel and chromium contents than this, all the way down to "high alloy cast irons," have also found use in the emergency period and some (not excluding good gray irons, up to 750 F) have established their merits for use at temperatures up to 1000 F. In addition, of course, there are other alloy combinations than those outlined here that are serving usefully for heat resistant castings.

Retorts for Magnesium Production

Probably the most severe service to which heat-resistant alloys have been subjected during the war program is in retorts for the production of magnesium by reacting dolomite with ferrosilicon[15]. The temperature is 2150 F, and a reduced pressure of 0.1 mm. of mercury is required. The alloys which have been used have been of the 35% Ni - 15% Cr, 20% Ni - 28% Cr, and 15% Ni - 28% Cr types. Work which had been done to develop a balanced composition for the 25 Cr - 12 Ni type was timely for this application, and the records indicate that this alloy, with a total nickel and chromium content of about 42%, has given a somewhat better performance than the other alloy with about 5 to 7% more of these scarce metals.

It was found early in this process that the high vacuum and the high operating temperature caused the tubes to collapse. Some relief could be obtained by thickening the tube wall, but this used more metal and slowed up the heating operation. An ingenious solution was found in that it was possible to heat up a collapsed tube, apply internal pressure, and expand it back to its normal position, after which it could be continued in use. Fig. 12 shows collapsed tubes, and it has been possible to expand them for a large number of times. Fig. 13 shows the number of hours in service and the number of times that the tubes have been expanded after collapsing. This particular application has taken a relatively large tonnage of heat resisting alloys.

Another severe application for alloys of this type has been containers or jigs for copper brazing, which involves a work temperature of 2050 F. One of the more difficult applications is the brazing of aircraft propellers, and in one application it was estimated that the finished form for containing the propeller would cost $5,000. This application requires high stability of the finished form, and warpage must be essentially eliminated. Several alloys are being tried out for this application, including 35-15 and 25-12 types. To be sure that the 25-12 type is wholly austenitic, in some cases the nickel content was increased to 15 and 20%. Numerous other applications of copper brazing are making similar demands on heat-resistant alloys.

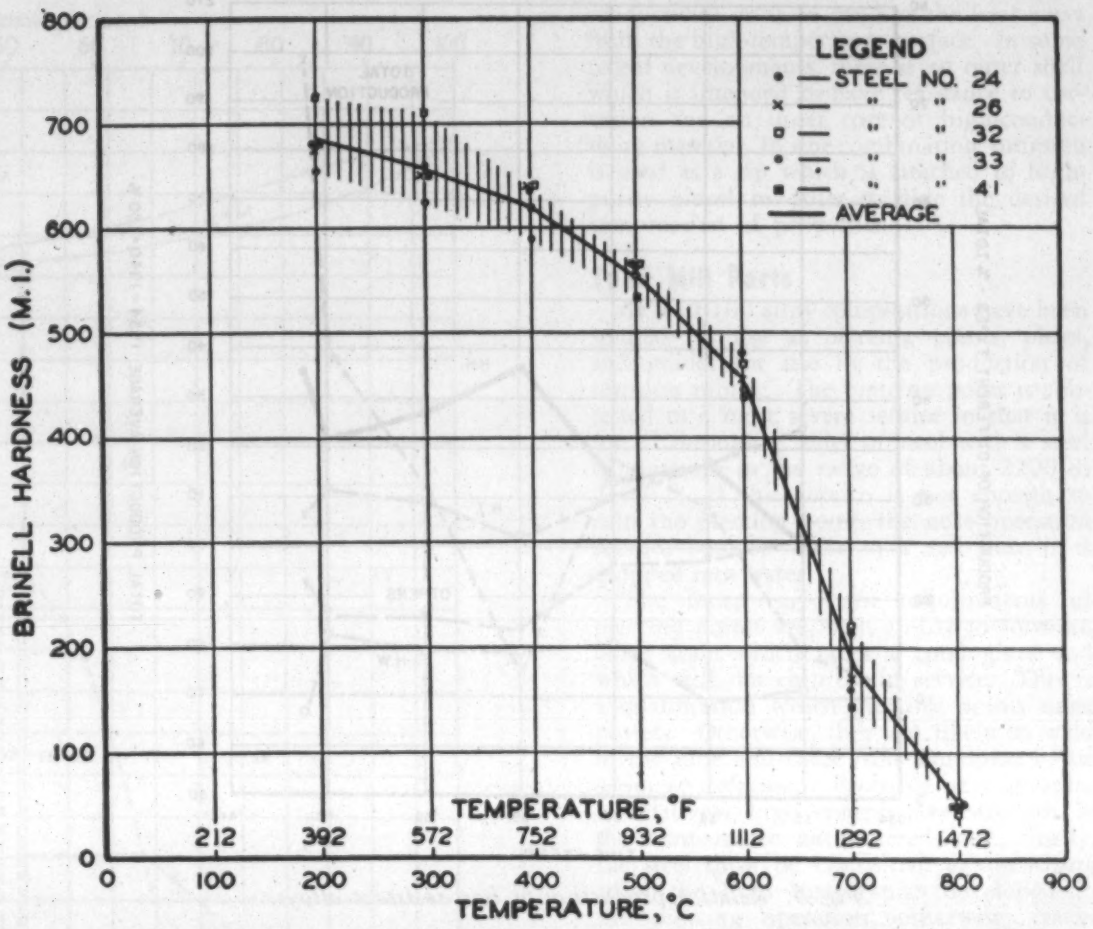


Fig. 4. Relation of testing temperatures to hardness of high-speed tool steels.

Wrought Alloys

Electrical Resistor Materials

Alloys for electrical resistors (heating elements for electric furnaces and electric heating appliances of various types) must resist oxidation and retain their strength at high temperatures not only because otherwise the element would soon break or sag, but also because any change in dimensions affects the electrical characteristics and therefore the heat output of the wire.

The 80% Ni - 20% Cr alloy has continued to be the most extensively used electrical resistor alloy. In the early days it was considered to have a maximum operating temperature of around 1800 to 1900 F, and A.S.T.M. specifications provided for life tests at 1000 C (1832 F). Improvements of great importance have been made in the last 10 to 15 yr. The general mechanism of improving the alloy was by a special method of deoxidation, for example, the addition of calcium so that 0.03 to 0.2% is retained in the alloy[4]. While other elements are disclosed in the patents covering this development, it is understood that calcium is the one most extensively used. It is claimed that the addition of calcium eliminates oxides at the grain boundaries, which materially improves the life of the alloy and results in its ability to withstand higher operating temperatures.

The A.S.T.M.[5] accelerated life testing temperature has now been raised to 2150 F, and the alloy is being used in furnaces for copper brazing at 2050 F for rather long periods of time and, to some extent, up to the temperature of 2200 to 2300 F required for treating high-speed tool steels. A similar improvement is reported for the resistor alloys of 60% Ni - 15% Cr - 25% Fe also. It is claimed that improvements in melting practice give the alloys an increased life of as much as 500%, or make it possible to increase the operating temperature by 100 to 200 F. This development illustrates the fact that an alloy may have satisfactory chemistry, at least by the usual analysis, but not have satisfactory microstructure or service performance.

Before leaving the electric resistor alloys, mention should be made of two alloys which have been developed within the past 15 yr. One of these contains about 25% Cr, 5% Al, and 3% Co, with the remainder substantially iron, and is marketed under the trade name of "Kanthal." The other is known as Smith No. 10 and contains approximately 37.5% Cr, 7.5% Al, and the remainder iron. These alloys make it possible to operate electrically heated furnaces up to 2300 F, or a heating element temperature of 2400 F.

Both of these alloys have some objectionable characteristics; for example, Kanthal grows and sags badly at the highest operating temperature, and Smith No. 10 is very stiff and brittle at ordinary temperatures. Both alloys are ferritic and relatively weak at elevated temperatures. However, they are both finding a place in industry, and Smith Alloy No. 10 is being used in both the cast and the wrought form. In addition to these two there are a few other useful iron-base resistor alloys containing aluminum and chromium with other elements.

Molybdenum, both in wire and ribbon form, has now been used for at least 30 yr. as an electric resistor element, but must be kept in a hydrogen atmosphere. Tungsten

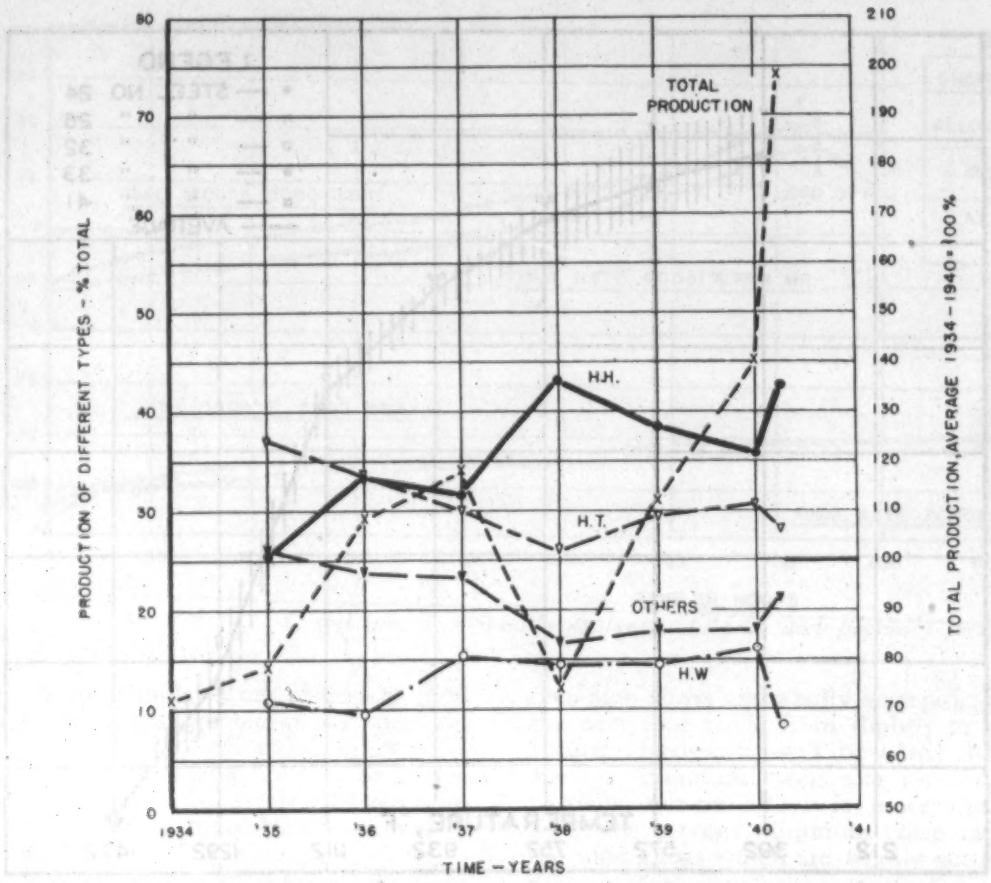


Fig. 5. Relative production of heat-resistant alloys.

is similarly used and can be operated at somewhat higher temperatures, but the elements are more difficult to shape.

The use of platinum as a heating element is quite old. It has been used as a pure metal but is used mostly as an alloy with rhodium, with the rhodium content varying from about 10 to 20%. Carter[6] reported the use of platinum and platinum-rhodium alloys at temperatures of 1300 to 1400 C (2372 to 2552 F) or even higher. He reports that the platinum-rhodium alloy gives a better life than the pure metal and, because of the low metal loss and the high resale value of the metal, that the cost of using the platinum-rhodium alloy is not excessive. The platinum-iridium alloy is less satisfactory because of a greater loss of the iridium by volatilization. Platinum with a platinum-rhodium alloy is our best noble metal thermocouple and is usable up to steel melting temperatures.

Table II. Composition of Exhaust-Valve Steels, Per Cent [1]

Type of Alloy	*Cr*	*Ni*	*C*	*Si*	*Mn*	*W*	*Mo*	*Others*
	8.5	—	0.45	3.2	—	—	—	—
	2.9	—	0.40	4.0	—	—	—	—
Martensitic	8.0	—	0.50	1.5	—	—	0.75	—
or	21.0	1.5	0.72	2.0	—	—	—	—
Pearlitic	13.5	0.88	1.05	1.9	—	3.5	0.63	—
Steels	13.3	0.65*	1.35	0.65*	—	—	0.70	2.5 Co
	3.5	—	0.60	—	—	14.0	—	—
	13.0	0.50*	1.1	0.50*	—	—	—	—
	11.0	1.5	0.5	0.20.	0.50	—	—	1.8 Al
	19.	8.	0.38	2.9	—	—	—	—
	21.5	11.5	0.25	0.85	—	—	—	—
	21.5	11.5	0.25	2.8	—	—	—	—
Austenitic	14.	14.	0.45	0.55	—	2.4	0.50*	—
Steels	14.	14.	0.45	3.0	—	2.4	0.50*	—
and	14.	26.	0.50	1.25	—	3.5	—	—
Alloys	25.	14.	0.45	0.55	—	—	2.5	—
	15.5	14.	1.10	2.5	—	—	—	—
	20.	32.	0.50	1.0	1.0	—	—	—
	3.5	12.	0.55	0.5	5.0	—	—	—
Transformation	12.8	7.4	0.30	2.5	—	—	—	—
Hardening	23.8	4.8	0.45	1.0*	—	—	3.0	—
Steels								

[1] Mean values given, balance iron. * Maximum.

A rather diversified group of materials, including many of those already mentioned in this section and nickel-base alloys of other types, is used for electronic tube filaments, grids, anodes, support wires and eyelets, with resistance to high temperatures an important factor in most cases.

Exhaust Valve Steels and Alloys

Truly remarkable advances have been made in the materials used in exhaust valves since the time of the last war. At that time the materials used in aircraft engines were quite limited, the most important one being the high-speed tool steel type, there being some use of a chromium steel, 14-12% Cr, and of a nickel-chromium-tungsten steel. As an item of interest, it may be pointed out that passenger automobiles at the end of World War I were using, at least in part, cast-iron exhaust valve heads, and the valves needed grinding in about every 1,000 miles.

There is no intention of attempting a complete historical review of the development in this field, but it was during the twenties that the material known as Silchrome, with about 8 to 9% Cr and about 3 to 4% Si, came into use. For passenger cars of that day, it was a marked improvement. However, this alloy is ferritic and is relatively weak at elevated temperatures, and its resistance to the leaded fuels was not good. High-speed steels continued to be used to some extent during the twenties.

Also during this period of time, the austenitic valve steels were developed, and many new compositions of the ferritic alloys were studied. Without going into great detail as to the compositions studied, the alloys given in Table II are illustrative and give an indication of the trend of these developments[9]. In the over-all picture, chromium is relied upon for resistance to oxidation and corrosion attack. It is sometimes supplemented by silicon, and a goodly number of the more recently developed materials contain tungsten and/or molybdenum. A few of them contain cobalt.

It was during the past 10 or 15 yr. that the internally-cooled valve (using metallic sodium as the internal coolant, for example) was introduced and has now found general application in aircraft engines, where it is necessary, because of the severe service, to get extra cooling so as to avoid overheating of the valve. Such a valve, with Stellite trim, is shown in Fig. 14. Also during this period, the use of Stellite as a valve facing material was introduced. Stellite is a cobalt-base alloy containing about 27% Cr, about 1.25% C, about 5% W, with small amounts of silicon and manganese. It has a high hardness and maintains its hardness at elevated temperatures, but is somewhat deficient in resistance to corrosion by the leaded fuels. A consideration of its analysis shows a carbon content of 1.25%, and, making the assumption that carbon combines with about 16 times its weight of chromium, it will be evident that the chromium remaining in the matrix of Stellite is only of the order of 7%. On this basis, the matrix does not contain a sufficient amount of chromium for good corrosion resistance at elevated temperatures in some environments.

Somewhat more recently, and studied first in England, a material known as Brightray has been used for valve facing. It is essentially a modification of the 80% Ni - 20% Cr type of electrical resistor alloy to which small amounts of manganese, silicon, iron, and carbon have been added. This alloy has somewhat better corrosion resistance

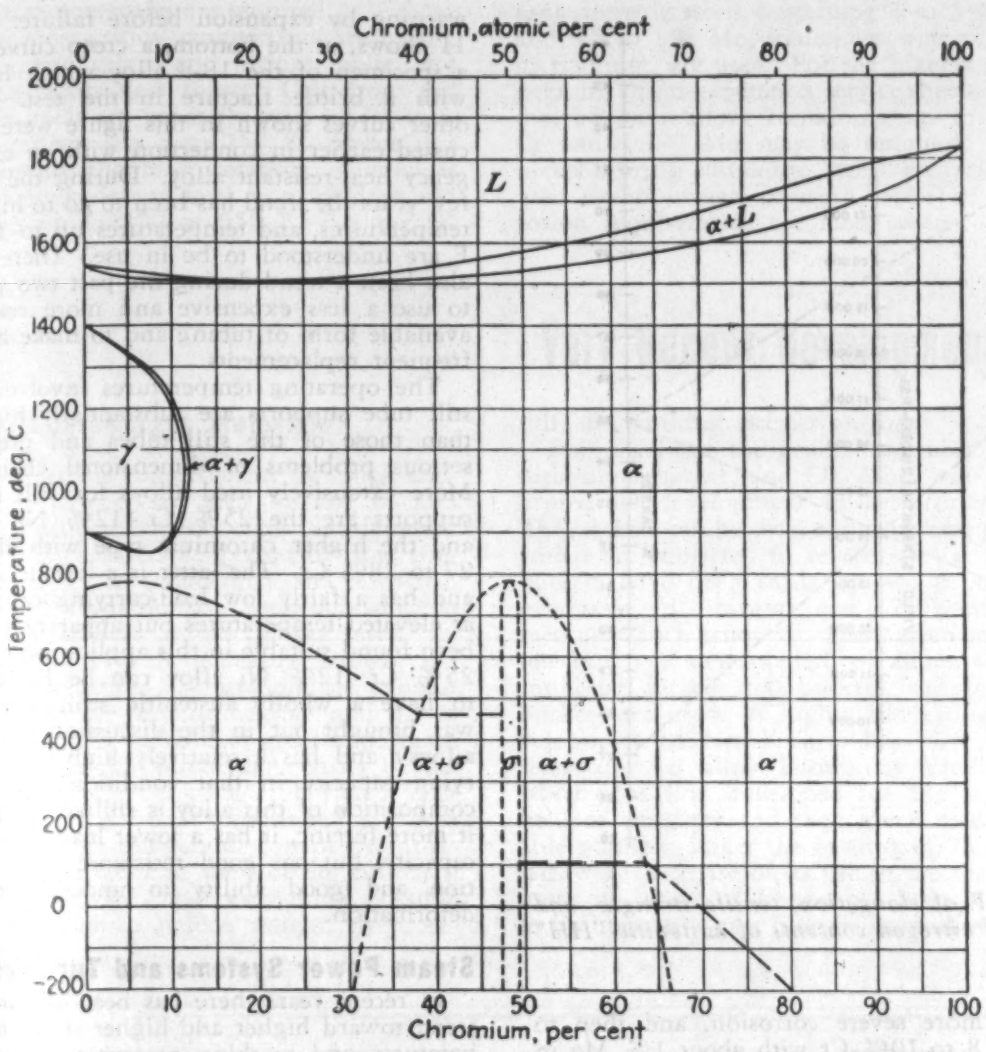


Fig. 6. Iron-chromium diagram (Kinzel and Crafts).

than Stellite. On the other hand, the alloy is much lower in hardness, both at room temperature and at valve-operating temperatures, and tends to deform in service. One of the problems facing industry at the present time is the development of an alloy having the hardness and wear resistance of Stellite and the corrosion resistance of the 80-20 alloy.

Valve-operating temperatures are known to vary over a rather wide range. More frequently the temperature is within the range of about 1200 to 1400 F. Two independent investigations on aircraft engines have indicated temperatures of about 1300 to 1350 F for exhaust valves working under heavy operating conditions. Under abnormal conditions and under conditions of pre-ignition, temperatures sufficient to melt valves have actually been reported. A very severe condition is encountered in aircraft during the take-off and in power dives.

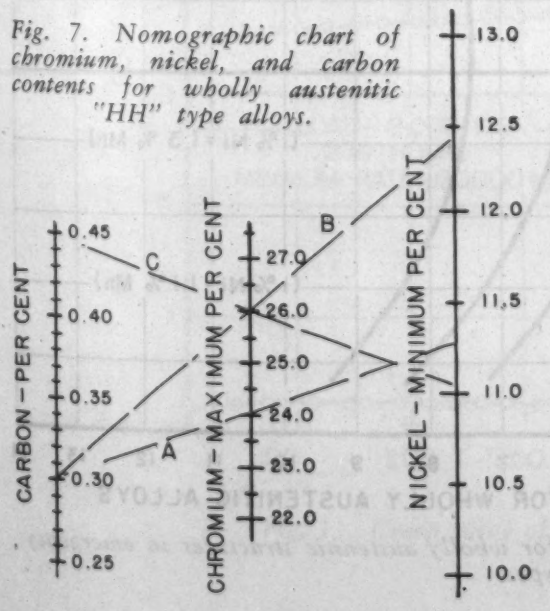


Fig. 7. Nomographic chart of chromium, nickel, and carbon contents for wholly austenitic "HH" type alloys.

Spark Plug Electrodes

Spark plug electrodes constitute a rather important problem in aircraft engines in particular, and in internal combustion engines in general. A relatively large number of materials have been used, but at present the more important are the nickel-base alloys, platinum, platinum alloyed with tungsten, commercially pure tungsten, and there is some use of stainless steels. Recent patents disclose alloys of platinum with molybdenum[2] and with tungsten[1] for electrode material. Nickel is alloyed with manganese and silicon in the simpler alloys, but it is also alloyed with manganese, silicon, and chromium, and a 1941 patent discloses a nickel-base alloy with the alloying elements, chromium, barium, columbium, iron, manganese, magnesium, and silicon[10]. The operating temperature for spark plug electrodes has been estimated at 1200 to 1400 F for the major portion of the electrode tip, but it is indicated that the surface temperature may be sufficient to volatilize some of the metals. Pre-ignition may cause melting.

The requirements of spark plug electrodes are probably not precisely known, but it is important that they have adequate resistance to attack by the products of combustion, including leaded fuel, and it is generally desirable that they have relatively high conductivity so as to conduct the heat away from the high-temperature surface. In some recent developments, there is an outer shell which is intended to have resistance to corrosion and an inner core of high-conductivity material. In one combination, tungsten is used as a tip which is attached to high-purity nickel in order to give the desired combination of properties.

Tube Mill Parts

At least 100 alloy compositions have been studied for use as piercing points, plugs, and guides for use in the production of seamless tubing. The piercing point is subjected to a most severe service in that it is forced through a billet of steel with a steel temperature in the range of about 2200 to 2400 F. If this service is not enough to ruin the piercing point, the next operation should, because while at a red heat it is dropped into water.

The more important requirements of piercing points are, first, ability to form an oxide scale which takes a good glaze and which will not chip off in service. This is a qualification which piercing points must possess. Otherwise, they are likely to weld to the tube and cause mill shutdown or be seriously deformed. Probably next in order is relatively high compressive strength at the temperature encountered, and, finally, the steel must be insensitive to quenching from the high temperature developed in the piercing operation; otherwise, cracks will result.

The steels which have been developed for this application contain all the way from

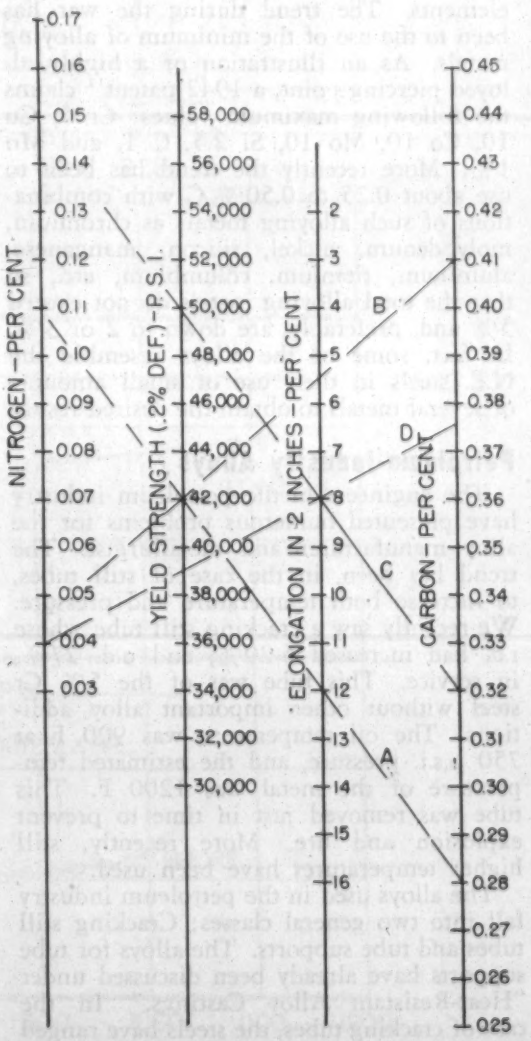


Fig. 8. Nomographic chart of relation of carbon and nitrogen to elongation and yield strength at room temperature of aged wholly austenitic "HH" type alloys.

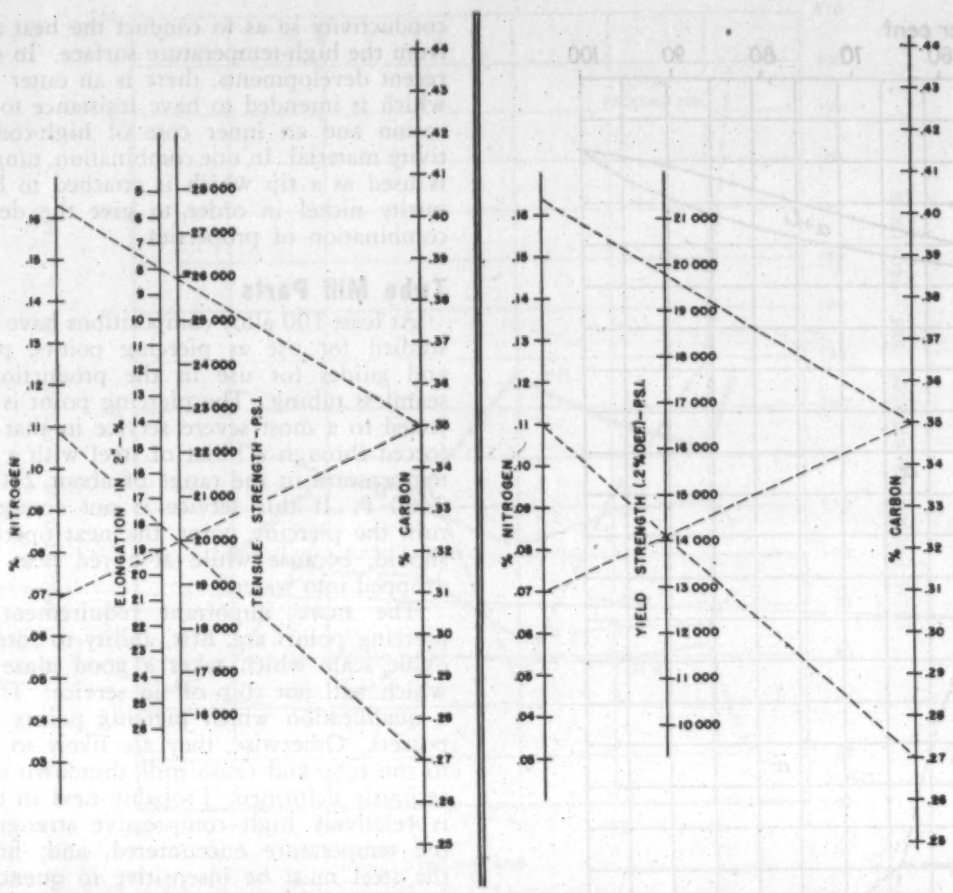


Fig. 9. Nomographic charts of the relation at 1600 F of elongation, tensile strength, and yield strength in short-time tension tests to carbon and nitrogen contents of austenitic "HH" type alloys.

about 2 up to 40% of special alloying elements. The trend during the war has been to the use of the minimum of alloying metals. As an illustration of a highly alloyed piercing point, a 1942 patent[11] claims the following maximum values: Cr 5, Cu 10, Co 10, Mo 10, Si 2.5, C 1, and Mn 1%. More recently the trend has been to use about 0.25 to 0.50% C with combinations of such alloying metals as chromium, molybdenum, nickel, silicon, manganese, aluminum, titanium, columbium, etc., so that the total alloying metals do not exceed 5% and, preferably, are down to 2 or 3%. In fact, some of the alloys resemble the N.E. steels in their use of small amounts of several metals to obtain the desired result.

Petroleum-Industry Alloys

The engineers in the petroleum industry have presented numerous problems for the alloy manufacturer and metallurgist. The trend has been, in the case of still tubes, to increase both temperature and pressure. We recently saw a cracking still tube whose i.d. had increased 6-20%, and o.d. 27%, in service. This tube was of the 5% Cr steel without other important alloy additions. The oil temperature was 900 F at 750 p.s.i. pressure, and the estimated temperature of the metal was 1200 F. This tube was removed just in time to prevent explosion and fire. More recently, still higher temperatures have been used.

The alloys used in the petroleum industry fall into two general classes: Cracking still tubes and tube supports. The alloys for tube supports have already been discussed under "Heat-Resistant Alloy Castings." In the case of cracking tubes, the steels have ranged from plain carbon steels through a variety of alloys, such as about ½ to 1% Mo, where there is little corrosion problem, to about 5% Cr and ½% Mo with a somewhat more severe corrosion, and then to about 8 to 10% Cr with about 1% Mo in the more severe corrosion problems; and some use has been made of the 18% Cr - 8% Ni alloys in the more severe corrosion applications. The use of 18-8 has not been permitted recently by Government regulations, but some of the earlier installations are still in operation.

In general, this type of alloy gives the best performance on the basis of resistance to corrosion by the petroleum and also resistance to scaling on the outside of the tube. In a few instances, unsatisfactory results have been encountered because the tubes failed with a brittle fracture with no warning by expansion before failure. Fig. 11 shows, at the bottom, a creep curve for a specimen of the 18-8 alloy which failed with a brittle fracture in the test. The other curves shown in this figure were discussed earlier in connection with an emergency heat-resistant alloy. During the past few years the trend has been to go to higher temperatures, and temperatures up to 1400 F are understood to be in use. There has also been a trend during the past two years to use a less expensive and more readily available form of tubing and to make more frequent replacements.

The operating temperatures involved in still tube supports are substantially higher than those of the still tubes and present serious problems of dimensional changes. More extensively used alloys for still tube supports are the 25% Cr - 12% Ni type and the higher chromium type with about 27 to 28% Cr. The latter is a ferritic alloy and has a fairly low load-carrying capacity at elevated temperatures but apparently has been found suitable in this application. The 25% Cr - 12% Ni alloy can be balanced to have a wholly austenitic structure (as was brought out in the discussion of cast alloys) and has a relatively high load-carrying capacity in that condition. As the composition of this alloy is shifted to make it more ferritic, it has a lower load-carrying capacity, but has good resistance to oxidation and good ability to undergo some deformation.

Steam Power Systems and Turbines

In recent years there has been a marked trend toward higher and higher steam temperatures and working pressures in boiler systems, maritime steam and turbine equipment, central station apparatus, etc. In 1930 the average steam temperatures for central station boiler installations were about 700 F and pressures around 500 p.s.i.; today the temperatures often run over 1000 F and pressures are higher than 1000 p.s.i. with some greater than 1500 p.s.i.

This advance means much more efficient steam generation, and when applied to ship power systems it means greater speed or more fuel capacity or more armament. For these higher pressures and temperatures alloy steels with superior resistance to oxida-

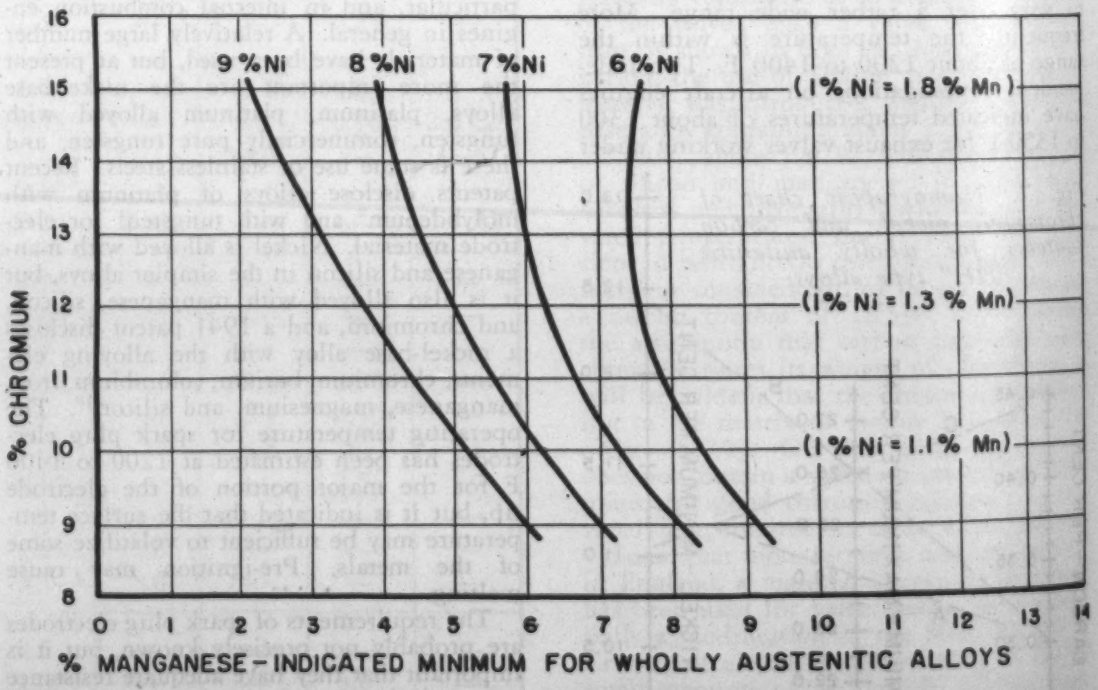


Fig. 10. Nickel and manganese requirements for wholly austenitic structures in emergency alloy types.

tion, steam attack and to mechanical failure at high temperatures are required.

The most critical components are tubing and piping, valves and fittings, bolts, and turbine shafts and rotors. Cast iron and carbon steels are generally used where temperatures are less than 750 F. Above this temperature the most common material is carbon-molybdenum steel pipe, forgings and castings up to 900 or 950 F. For the remainder of the steam-system temperature range ferritic steels containing 1 to 5% Cr and 0.5 to 1% Mo, sometimes with silicon or titanium, are used. For the highest temperature steam-generation service chromium-molybdenum alloys containing up to 9% Cr and 1.3% Mo may be required. The nickel-bearing austenitic steels are seldom used except where pressure, stress or corrosion requirements are most severe.

Steam temperatures are in the neighborhood of those at which hydrogen is formed. Solberg, Hawkins and Potter[21] studied the corrosion of various steels at temperatures up to 1400 F and pressures up to 1600 p.s.i. and found that the only steels that formed thin, porous and tightly adherent scale in such service were those containing more than 7% Cr.

Very Recent Developments

Turbosupercharger Materials

An extreme requirement of high-temperature service has been for the buckets for turbosuperchargers. This development was for a considerable period of time considered as secret, confidential, and restricted, but now information has been published so that the subject is no longer even restricted[16, 17]. As is generally known, the turbosupercharger operates on the exhaust gases from the aircraft engines and drives a supercharger, which is of great importance at high altitudes where the density of the air may be only 1/5 to 1/7 of what it is at sea level. The gases encountered are at a relatively high temperature, or of the order of 1400 to 1500 F in some of the estimates, and it is obvious that everything possible must be done to reduce weight. As a result, the working stresses are high.

Fig. 15 shows the general assembly of a turbosupercharger, and Dr. Moss who pioneered its development in this country[17]. The buckets can be seen, and it is these parts which are subjected to severe service. The buckets have been made by two principal processes: (1) forging and (2) precision casting. Much study has been given to the selection and development of alloys which could be forged into buckets, and forged buckets are used. A highly interesting development in cast buckets has now been released. An alloy known as Vitallium, which was first developed for use in the field of dentistry and then given considerable publicity under the heading of "human hardware" because of its use in the replacement or repair of bones, has been shown to be important as a heat-resistant alloy and is used as the buckets in turbosuperchargers. Fig. 16 shows a rather complicated dental casting made of this alloy, and the accompanying Table gives the properties of the cast alloy. (Supplied by Austenal Laboratories, Inc.) The alloy is of a cobalt base containing about 65% Co, about 30% Cr, and about 5% Mo. Vitallium has good properties at supercharger bucket operating temperatures and is outstanding in its adaptability for precision castings.

While the castings originally developed in the field of dentistry weighed only fractions of an ounce, new developments permit the production of castings weighing from 1 to 2 lb. Precision casting has also been applied to other alloys. Larger castings are now being produced, and probably the upper limit will be of the order of 100 to 200 lb.

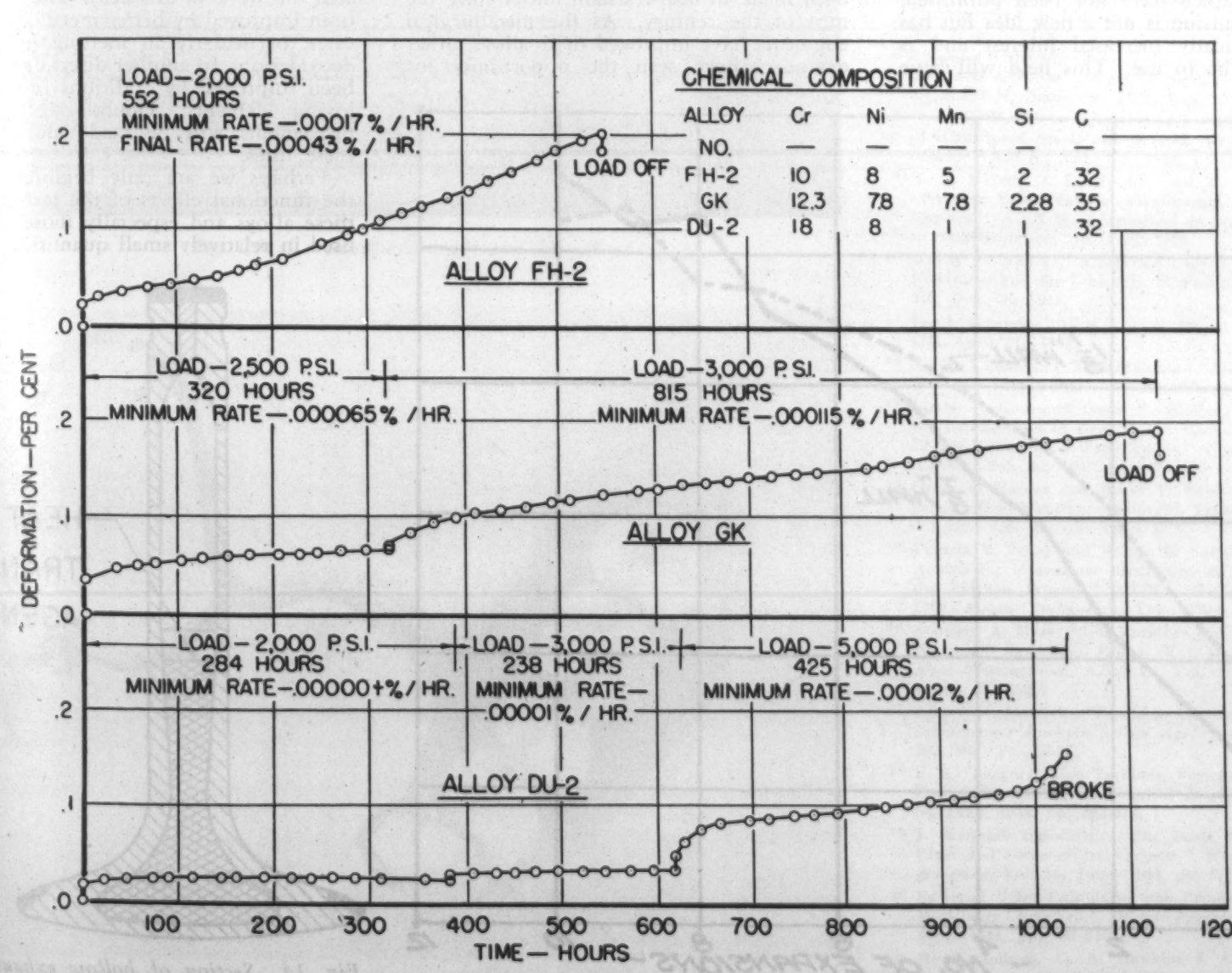


Fig. 11. Creep curve of 18-8 alloy (DU) showing brittle fracture; also of two emergency steels.

*Table III. Properties of Vitallium Castings.**

Specific gravity	8.29
Melting range, deg. F	2450 - 2500
Hardness	Rockwell "C" 43
Modulus of elasticity, p.s.i.	30,000,000
Tensile strength, p.s.i.	110,000
Yield point, p.s.i.	85,000
Elongation, %	3.0
Reduction in area, %	5.0

* Private communication from Austenal Laboratories, Inc.

Gas Turbines and Jet Propulsion

Two other high-temperature applications of metals and alloys should be mentioned: (1) combustion turbines ("gas turbines")[18, 19] and (2) jet propulsion[20]. Combustion turbines are in use but at relatively low temperatures and consequently at low efficiencies. Engineers recognize the marked increase in efficiencies attainable at higher operating temperatures, and this poses the problem of suitable alloys. Whereas temperatures of the order of 1000 F to possibly 1200 F are in use, greatly improved efficiencies are evidently possible if the operating temperature can be increased to the order of 1400 to 1500 F. Search for suitable alloys is in progress and some success has been achieved, but the results obtained have not been published.

Jet propulsion is not a new idea but has received greatly increased interest and is known to be in use. This field will have special requirements for metals to operate at elevated temperatures and will be an interesting metallurgical development when the information becomes available.

Thus, many important developments have been made in heat-resistant alloys since the turn of the century. As the metallurgical engineers have improved their alloys, other engineers have seen the opportunity for improving processes or making processes possible if they could have alloys of still higher properties at given operating temperatures or capable of operating at higher temperatures. War demands have accelerated the work in this field. The alloys have been improved by better metallurgical processes, particularly in melting practice and deoxidation. In another direction, they have been improved by additions of special alloying elements. Doubtless, further improvements will be made along both of these lines.

Perhaps we are only beginning to find the functional effects of the metals used in these alloys and especially those which are used in relatively small quantities, and it is

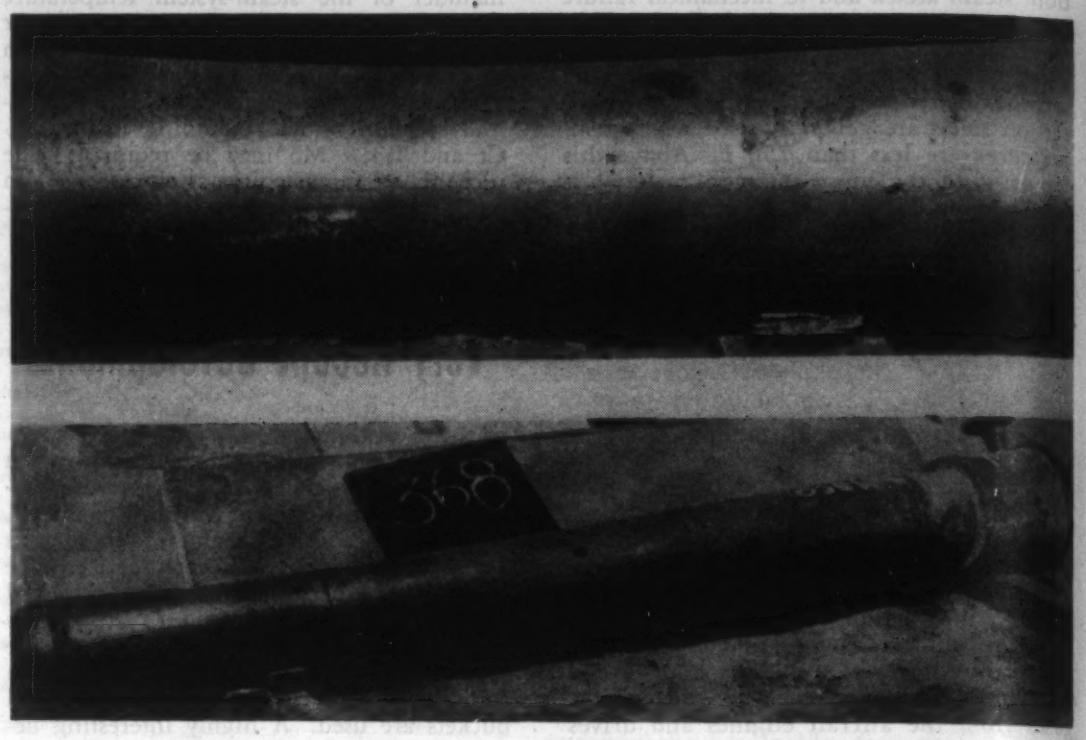


Fig. 12. Collapsed retort tubes for magnesium productions.

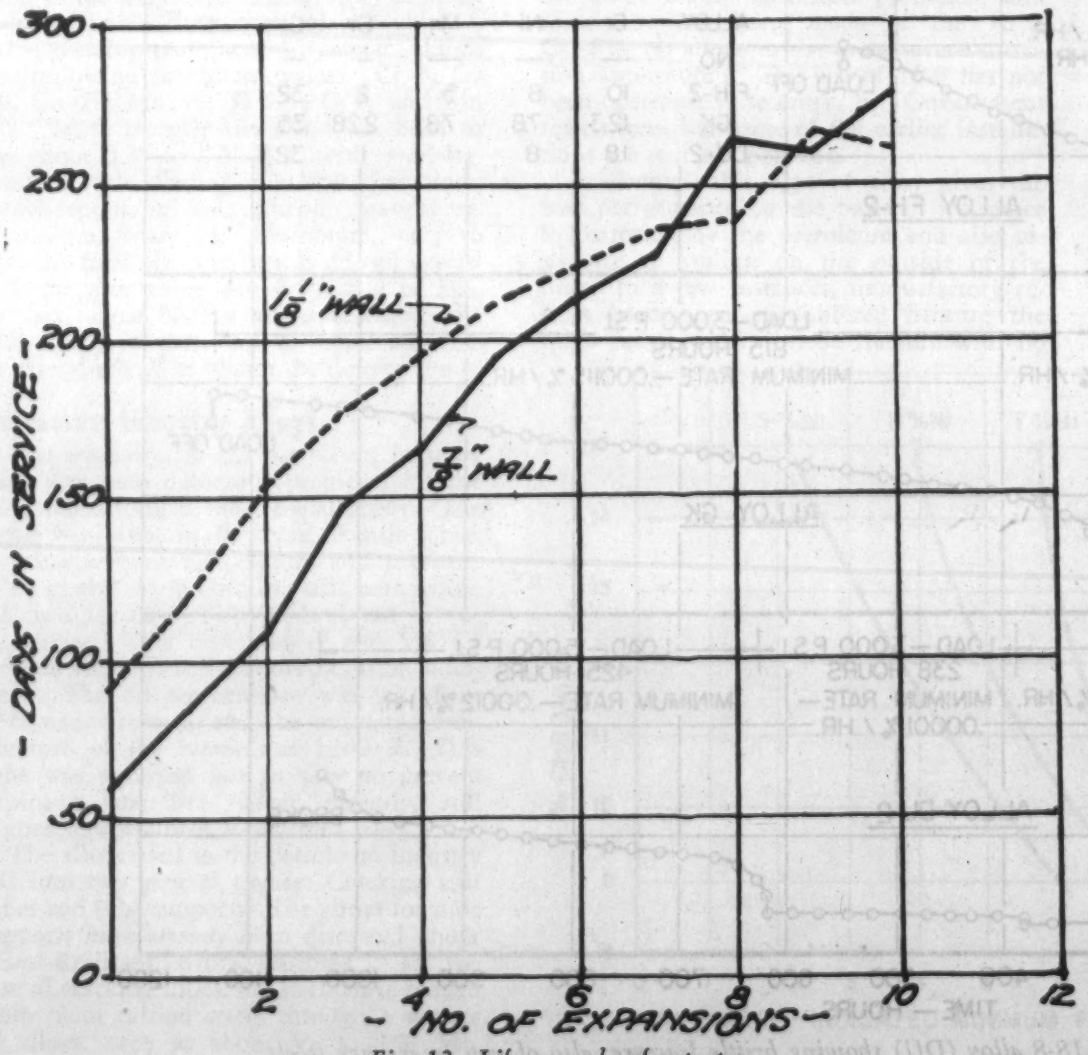


Fig. 13. Life records of retorts.

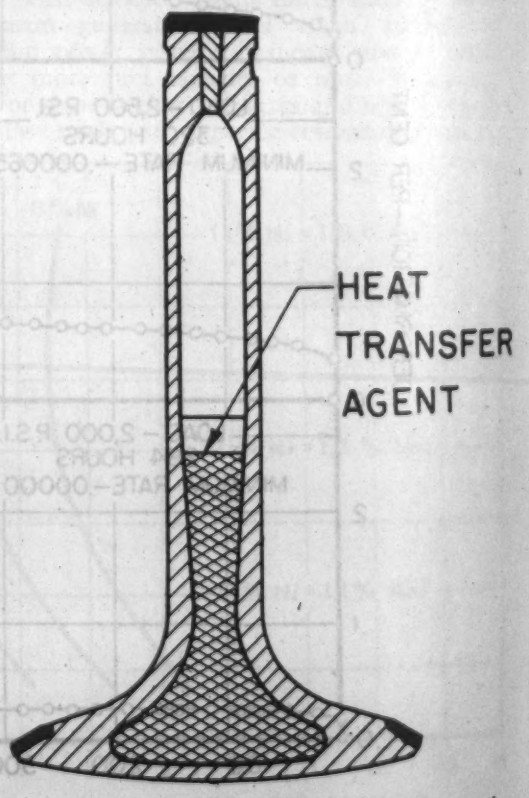


Fig. 14. Section of hollow exhaust valve showing Stellite trim.

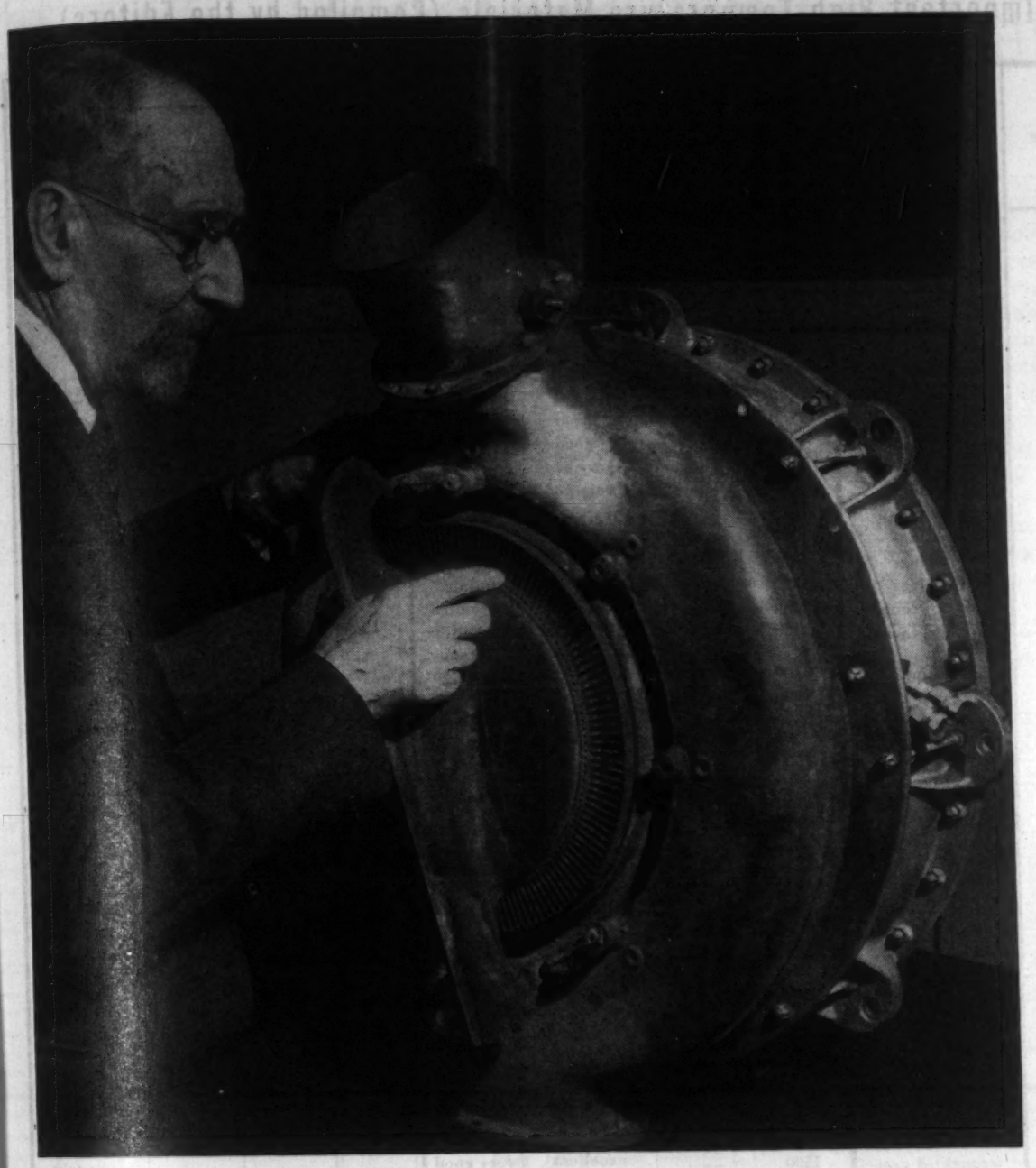


Fig. 15. Turbosupercharger and Dr. Moss.

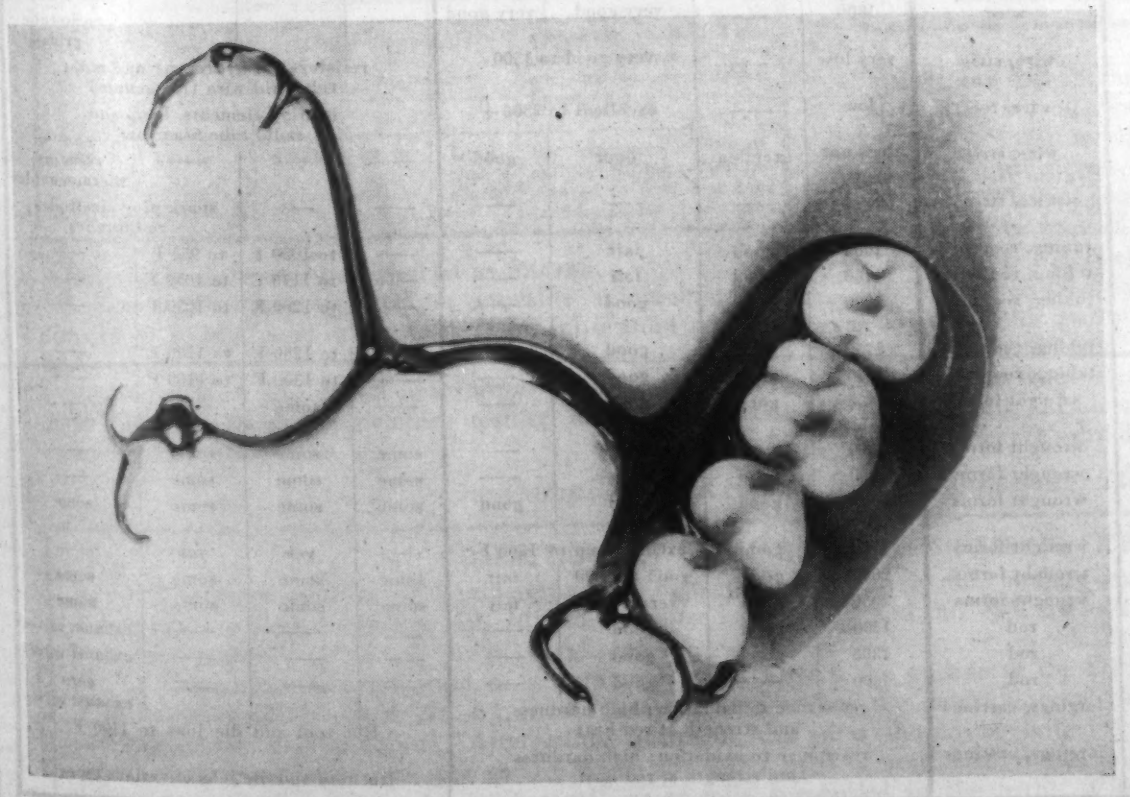


Fig. 16. Dental casting of Vitallium alloy.

probably not out of place to say that there are special metals which might be referred to as vitamins in metallurgy. It is by learning the functional effects of these special alloying metals and using them in the optimum concentration and probably taking advantage of several of them in a given alloy that new progress may be anticipated. However, the metallurgist working on alloys for high-temperature service will probably never have a finished program because as soon as an alloy is developed which is adequate for a given temperature and stress, some engineer will immediately find that he could do a better job or carry out a new process if he had an alloy which would stand higher temperatures and other more severe service conditions. It is hoped that this necessarily brief review will be of help to both groups.

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More data on high-temperature materials on next page.

General Listing of the Most Important High-Temperature Materials (Compiled by the Editors)

Type, Name or Designation	Composition (%) and Structure A = Austenitic or nickel-base F = Ferritic M = Martensitic, hardenable	Usual Forms	High-Temperature Properties				Chief Fields of Use [1]			
			Resists Scaling to : °F	Resistance to Sulfur Compounds	Relative Creep Strength	Resistance to Heat Shock	Furn. Parts & Heat Treat. Equip.	Petro. Refin. Equip. & Parts	Steam, Turbine & Power Equip.	Others
CM-25*	19-22 Ni, 8-11 Cr,0.25 Cr; A	castings	1500	poor	good	good	—	some	—	chemical
HB,* 18 Cr	18-22 Cr, 2 max. Ni; F	castings	1600	good	fair	fair	yes	some	some	—
HC,* 28 Cr	27-30 Cr, 3 max. Ni; F	castings	1800	good	fair	poor	yes	some	some	—
HD,* 28-5	27-30 Cr, 3-6 Ni; A-F	castings	1900	good	fair	poor	yes	yes	—	—
HE,* 29-9	27-30 Cr, 8-11 Ni; A-F	castings	1950	good	good	poor	yes	yes	some	—
HH,* 25-12	23-27 Cr, 10-13 Ni; A	castings	2000	good	good	fair	yes	some	some	—
HK,* 25-20	23-26 Cr, 19-21 Ni; A	castings	2050	good	good	fair	yes	yes	some	—
HL,* 30-20	28-32 Cr, 19-21 Ni; A	castings	2100	good	good	fair	yes	yes	—	—
HP,* 30-30	28-32 Cr, 29-31 Ni; A	castings	2100	fair	good	good	yes	—	—	—
HS,* 30-10	29-32 Ni, 8-12 Cr; A	castings	1800	poor	good	good	yes	yes	—	—
HT,* 35-15	34-37 Ni, 13-17 Cr; A	castings	1900	poor	very good	very good	yes	yes	—	—
HU,* 38-18	37-40 Ni, 17-21 Cr; A	castings	1900+	poor	very good	very good	yes	yes	—	—
HW,* 60-12	59-62 Ni, 10-14 Cr; A	castings	2000	poor	excellent	excellent	yes	yes	—	—
HX,* 66-18	65-68 Ni, 15-19 Cr; A	castings	2000+	poor	excellent	excellent	yes	yes	—	—
Emergency Alloy	10-12 Cr, 4-10 Ni, 2-12 Mn, 2 Si; A	castings	1500	fair	good	fair	—	—	—	—
18-8 or 18-9	18-20 Cr, 8-10 Ni; A	castings	1500	fair	good	fair	—	some	—	chemical
Inconel	77 Ni, 14 Cr, 6 Fe, 2 Si; A	cast & wrought	2000+	poor	excellent	excellent	yes	yes	—	—
Stellite	27 Cr, 5 W, 1.25 C, rest Co	castings, facings	2100+	—	excellent	excellent	—	—	yes	exhaust valves, hot dies
Vitallium	30 Cr, 5 Mo, 65 Co	castings	2100+	—	excellent	excellent	—	—	yes	—
Ni-Resist	Cast iron; 14.3 Ni, 4 Cr, 5 Cu; A	castings	1500	good	resists growth	—	some	some	some	chemical
Meehanite HR	Special gray iron, small % Cr	castings	1500	good	adequate for light loading up to 1000-1500 F		some	some	some	chemical; hot dies
Alloy Cast Irons	Cast iron contg. Ni, Cr, Mo	castings	1500	good	ditto		some	some	some	chemical; hot dies
80-20 Alloy	80 Ni, 20 Cr	rod, wire, etc.	2100+	poor	very good	excellent	some	—	—	electric resistors, exhaust valves
60-15 Alloy	60-65 Ni, 14-16 Cr, rest Fe; A	rod, wire, etc.	2000	poor	very good	excellent	some	some	—	resistors to 1800 F
35-15 Alloy	30-35 Ni, 14-18 Cr, rest Fe; A	rod, wire, etc.	1900	poor	good	good	some	some	—	resistors to 1400 F
30-5 Alloy	30 Ni, 3-5 Cr, rest Fe; A	rod, wire, etc.	1800	poor	good	good	some	some	—	resistors to 1100 F
90-10 (Chromel P)	90 Ni, 10 Cr; A	rod, wire, etc.	1900+	poor	good	good	high-temperature thermocouples		—	—
Kanthal	25 Cr, 5 Al, 3 Co; F	rod, wire, etc.	2300	very good	poor	fair	—	—	—	resistors to 2300 F
Smith No. 10.	37.5 Cr, 7.5 Al, rest Fe	rod & castings	2400	very good	poor	fair	some	—	—	resistors to 2400 F
Pure Nickel	99+ Ni	wrought & cast	1700	very poor	poor	good	—	some	—	electronic filaments
K-42-B	40-50 Ni, 20-30 Co, 1-4 Ti, 5-15 Fe, 15-30 Cr	wrought & cast	1500	—	excellent	very good	—	—	—	radio tube parts
Konal Alloys	75 Ni, 18 Co, 5 Fe, 2 Ti	rod, wire, etc.	1500	—	very good	very good	—	—	—	electronic tube elements
Nickel-Moly Alloy	45 Ni, 45 Fe, 10 Mo	wire	1800	—	very good	very good	—	—	—	radio tube grids
Molybdenum	99.9+ Mo	wire, strip	very low	—	very good to 1500		resistors (in hydrogen) and radio tube grid wire (in vacuum)			
Tungsten	99.9+ W	wire, rod	low	—	excellent to 2500+		heating elements, lamp and radio tube filaments			
Platinum-Rhodium	10-20 Rh, rest Pt	wire, strip	does not oxidize	excellent	poor	good	—	—	—	resistors, thermocouples
Manganese-Nickel	2-5 Mn, 1-4 Si, rest Ni	wire, strip	1800	—	—	—	—	—	spark plug electrodes; radio tubes	
Carbon-moly Steel	0.5 C, 0.5-1 Mo; M	tubing, rod, strip	1000	good	fair	—	—	to 1050 F	to 950 F	—
Chrome-moly Steels	1.25-3 Cr, 0.5-1 Mo; M	tubing, rod, strip	1100	good	fair	—	—	to 1175 F	to 1050 F	—
4-6 Chrome-moly, types‡ 501,502	4-6 Cr, 0.5 Mo steel; M	tubing, rod, strip	1200	good	good	—	—	to 1200 F	to 1050 F	—
7% Chromium	7 Cr, 0.5 Mo, 0.5-1 Si steel; M	tubing, rod, strip	1250	good	good	—	—	to 1250 F	to 1100 F	—
8-10 Chromium	8-10 Cr, 0-1.5 Mo; M	tubing, rod, strip	1300	good	good	—	—	to 1300 F	to 1100 F	—
Types‡ 410, 416, 420, 420 F	10-14 Cr, sometimes ½ Mo; M	wrought forms	1400	good	good	—	—	some	—	—
Types‡ 430, 440	14-18 Cr, sometimes Si & Mo; F	wrought forms	1600	good	fair	—	some	some	some	—
Type‡ 446	23-30 Cr; F	wrought forms	2000	good	fair	—	some	some	some	—
18-8; types‡ 301, 302, 303, 304, 321, 347	16-20 Cr, 6-10 Ni, sometimes ½ Mo; A	wrought forms	1700	good	good	good	some	some	some	some
Type‡ 316	16 Cr, 10-13 Ni, 2-3 Mo; A	wrought forms	1700	good	excellent up to 1300 F		—	yes	yes	—
25-12; type‡ 309	22-25 Cr, 12-15 Ni; A	wrought forms	2000	good	good to 1600	fair	some	some	some	some
25-20; type‡ 310	24-26 Cr, 19-22 Ni; A	wrought forms	2050	good	very good	fair	some	some	some	some
Silchrome	8-9 Cr, 3-4 Si steel; M	rod	1300	good	good	—	—	—	—	exhaust valves
20-2 Alloy	19-23 Cr, 1-2 Ni, 1.25-2.75 Si	rod	1800	good	good	—	—	—	—	exhaust valves
14-14-2 Alloy	13-15 Cr, 13-15 Ni, 1-3 W	rod	1600	—	good	—	—	—	—	aero exhaust valves
18-4-1	18 W, 4 Cr, 1 V steel	forgings, castings	resistance to oxidation; high hardness and strength at red heat				Hot tool and die jobs to 1100 F			
Hot-work die steels	1-12 Cr, 1-15 W, 0-4 Co; Mo, Ni, V	forgings, castings	resistance to oxidation; high hardness and strength at red heat				Hot tool and die jobs of various types			

[1] Chief field of use indicated by word "yes," other fields by "some."

‡ American Iron and Steel Institute Type Nos.

* Alloy Casting Institute designations.

More data on high-temperature materials on next page.

METALS and ALLOYS

Engineering File Facts

NUMBER 75
March, 1945

Industrial Felt

The Society of Automotive Engineers has set up a classification of felts on the basis of wool content, as follows:

S.A.E. No.	Trade Designation	Nominal Fiber Content		Color	Uses
		Wool, %	Cotton, %		
F-1	Back Check	100	——	White	For oil retention when felt is not compressed; for feeding low viscosity oil; and where unusual strength and hardness are required.
F-2	Back Check	100	——	Any Color	Same as F-1, but slightly lower in quality.
F-3	Back Check	95-100	5	Gray	
F-5	Extra Firm Pad	100	——	White	For dust shields, wipers, grease retainer washers, wicks; in uses where resiliency is required.
F-6	Extra Firm Pad	100	——	Gray	
F-7	Extra Firm Pad	85-95	5-15	Gray	
F-10	Firm Pad	100	——	White	For grease and oil retention where the felt is confined and compressed.
F-11	Firm Pad	100	——	Gray	
F-12	Firm Pad	90-95	5-10	Gray	
F-13	Firm Pad	80-85	15-20	Gray	For sound deadening, chassis strips, spacers, dust shields, etc., when abrasion and wear are not important.
F-15	Firm Pad	60-65	35-40	Gray	
F-26	Soft Pad	50-55	45-50	Gray	For packing or padding when held between other materials — not recommended for mechanical purposes.
F-50	Ball Bearing Felt	100	——	White	For ball- and roller-bearing oil retainer washers —for mechanical purposes requiring an accurate, thin, smooth felt.
F-51	Ball Bearing Felt	100	——	Gray	Same as F-50, but not as accurately sized or long-lived — suitable for thin cut parts, as gaskets, liners, etc.
F-55	Lining	80-85	15-20	Gray or Black	For anti-squeak strips, and for lining when cemented to fiber board or metal panels.

Felt applications may be classified as follows:

Sealing applications—guides for movable automobile windows, dust seals around instrument cases, lubrication seals for bearings, etc.

Heat insulation and sound absorption—as a lining for aircraft cabins, constant temperature testing rooms, for certain types of office equipment, etc.

Wicking applications—for bearing lubrication by capilary action, moistening devices, etc.

Shock absorption and surface protection—as a protective base for telephones and similar items, buffer blocks for hammer blows, buffer strips for door frames, etc.

Filtering—filter cloths or bags for clarifying solvents, lacquers, oils, enamels, dopes, etc.

Polishing—as wheels or pads for polishing saw steel, plumbing fixtures and other metal parts as a preliminary to electroplating, for polishing glass, plastics, pottery, etc.

Vibration isolation—to prevent transmission of vibration in machine tools, hammers, etc.

Felts may be measured in lb. per sq. yd. or in oz. per linear yd. 60 in. wide. The established sizes in the industry are:

S.A.E. No.	Weight of Felt, Lb. per Sq. Yd. (60 In. Wide)											
	Nominal Thickness, In.											
	1/8		3/16		1/4		5/16		3/8		1/2	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
F-1	1.9	2.1	2.85	3.15	3.8	4.2	4.75	5.25	5.7	6.3	7.6	8.4
F-2	1.9	2.1	2.85	3.15	3.8	4.2	4.75	5.25	5.7	6.3	7.6	8.4
F-3	1.8	2.1	2.71	3.15	3.61	4.19	4.50	5.24	5.41	6.29	7.21	8.39
F-5	1.45	1.61	2.18	2.40	2.91	3.21	3.63	4.01	4.36	4.82	5.81	6.43
F-6	1.45	1.61	2.18	2.40	2.91	3.21	3.63	4.01	4.36	4.82	5.81	6.43
F-7	1.42	1.64	2.12	2.46	2.83	3.29	3.53	4.11	4.25	4.93	5.66	6.58
F-10	1.01	1.11	1.51	1.67	2.02	2.24	2.53	2.79	3.03	3.35	4.04	4.46
F-11	0.98	1.14	1.47	1.71	1.97	2.29	2.48	2.84	2.95	3.43	3.93	4.57
F-12	0.98	1.14	1.47	1.71	1.97	2.29	2.48	2.84	2.95	3.43	3.93	4.57
F-13	0.98	1.14	1.47	1.71	1.97	2.29	2.48	2.84	2.95	3.43	3.93	4.57
F-15	0.98	1.14	1.47	1.71	1.97	2.29	2.48	2.84	2.95	3.43	3.93	4.57
F-26	0.86	1.04	1.28	1.56	1.71	2.09	2.07	2.53	2.56	3.14	3.42	4.18

S.A.E. No.	Weight of Felt, Oz. per Yd. (60 In. Wide)							
	Nominal Thickness, In.							
	0.050	0.055	0.060	0.065	0.070	0.075	0.080	0.085
F-50	20	22	24	26	28	30	32	34
F-51	20	22	24	26	28	30	32	34
F-55	15.5	17	18.5	20	21.5	23	24.5	26

Felt can be obtained in a variety of finishes. When used with ball- or roller-bearings, the felt is sheared on both sides. A sheared and sanded surface is offered for lubricating and filtering applications. Polishing felts require a rough or fuzzy surface. When a compact or smooth finish is desired, the felts are ironed or pressed.

When a water-repellent felt is required, as for weather stripping, the material is treated with a moisture-resistant material. Felts for stamp pads, tape moisteners, etc., are treated so as to possess high wettability. Stiffening treatments may be given felts when clean cutting or good resistance to distortion are needed. Mildewproofing, flameproofing and mothproofing treatments are available when required.

Compiled by Kenneth Rose, Engineering Editor

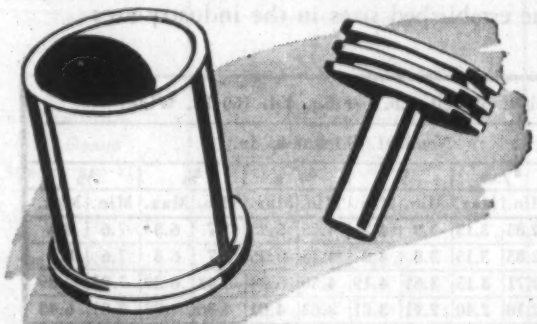
CORRECTIONS OF THE JANUARY "ENGINEERING FILE FACTS"

The three sections of Engineering File Facts that appeared in the January issue were erroneously numbered. They should have been numbered 69, 70 and 71 instead of 66, 67 and 68. We are asking our readers to make this correction in their copies.

The unfortunate omission of a paragraph of text from the outline of the Dichromate Treatment, AN-M-12 Type 3, in Engineering File Facts No. 67, in the January issue, makes the description of this process incomplete. The following paragraph should be added: "After either treatment, the parts should be boiled for 45 min. in a 10 to 15% sodium dichromate solution (1 lb. per gal.). When the water used is very hard, a little calcium or magnesium fluoride may be added to the dichromate, ¾ oz. per gal., or as solid suspended in the bath. With addition of fluoride, treatment time can be reduced to 30 min."

ADD YEARS OF SERVICE TO WORKING PARTS

USE STAINLESS — SURFACE HARDENED



"YOU SOLVED OUR PROBLEM!"

says the chief engineer of a prominent manufacturer of pressure reducing valves

"Surface hardened stainless steel proved to be the answer for prolonging the life of the working parts of our pressure reducing valves —even though the following hazards always are present:

"Dry, sliding friction under high temperatures rasps away at the surface of cylinder lining and piston wall . . . high pressure steam at 600 psi. develops pressure-cutting velocities to ruin valve seats . . . heat—750° of it—places heavy strain on valve stems and close fitting surfaces.

"The glass-hard surface provided by the Stainless Surface Hardening Process plus the inherent corrosion resisting qualities of Stainless Steel licked our problem, I'm glad to say."

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STAINLESS SURFACE HARDENING CO.

255 BENT STREET, CAMBRIDGE 41, MASS.

SUBSIDIARY OF INDUSTRIAL STEELS, INC.

NUMBER 76
March, 1945

Standard Gage Sizes

Gage No.	U. S. Standard	Manufacturers' Std. for Sheet Steel	Birmingham or Stubs'	Am. or Brown & Sharpe's	Washburn & Moen	British Standard	London or Old English	Paris or French Gage	Am. Zinc Gage	Am. Std. Preferred Thicknesses	Copper Sheet and Strip Cold Rolled to Weight	
											Wt. per sq. ft. oz.	Theoretical thickness in.
0000000	0.500				0.4900	0.500						
000000	0.469			0.5800	0.4615	0.464						
00000	0.438			0.5165	0.4305	0.432						
0000	0.406		0.454	0.4600	0.3938	0.400	0.454				32	0.0431
000	0.375		0.425	0.4096	0.3625	0.372	0.425				28	0.0377
00	0.344		0.380	0.3648	0.3310	0.348	0.380				24	0.0323
0	0.312		0.340	0.3249	0.3065	0.324	0.340	0.0197			20	0.0270
1	0.281		0.300	0.2893	0.2830	0.300	0.300	0.0236	0.002		18	0.0243
2	0.266		0.284	0.2576	0.2625	0.276	0.284	0.0276	0.004		16	0.0216
3	0.250	0.2391	0.259	0.2294	0.2437	0.252	0.259	0.0315	0.006		14	0.0189
4	0.234	0.2242	0.238	0.2043	0.2253	0.232	0.238	0.0354	0.008	0.224	12	0.0162
5	0.219	0.2092	0.220	0.1819	0.2070	0.212	0.220	0.0394	0.010	0.200	10	0.0135
6	0.203	0.1943	0.203	0.1620	0.1920	0.192	0.203	0.0433	0.012	0.180		
7	0.188	0.1793	0.180	0.1443	0.1770	0.176	0.180	0.0472	0.014	0.160		
8	0.172	0.1644	0.165	0.1285	0.1620	0.160	0.165	0.0512	0.016	0.140		
9	0.156	0.1495	0.148	0.1144	0.1483	0.144	0.148	0.0551	0.018	0.125		
10	0.141	0.1345	0.134	0.1019	0.1350	0.128	0.134	0.0591	0.020	0.112		
11	0.125	0.1196	0.120	0.0907	0.1205	0.116	0.120	0.0630	0.024	0.100		
12	0.109	0.1046	0.109	0.0808	0.1055	0.104	0.109	0.0709	0.028	0.090		
13	0.0938	0.0897	0.095	0.0720	0.0915	0.092	0.095	0.0787	0.032	0.080		
14	0.0781	0.0747	0.083	0.0641	0.0800	0.080	0.083	0.0866	0.036	0.071		
15	0.0703	0.0673	0.072	0.0571	0.0720	0.072	0.072	0.0945	0.040	0.063		
16	0.0625	0.0598	0.065	0.0508	0.0625	0.064	0.065	0.1063	0.045	0.056		
17	0.0562	0.0538	0.058	0.0453	0.0540	0.056	0.058	0.1181	0.050	0.050		
18	0.0500	0.0478	0.049	0.0403	0.0475	0.048	0.049	0.1339	0.055	0.045		
19	0.0438	0.0418	0.042	0.0359	0.0410	0.040	0.042	0.1535	0.060	0.040		
20	0.0375	0.0359	0.035	0.0320	0.0348	0.036	0.035	0.1732	0.070	0.036		
21	0.0344	0.0329	0.032	0.0285	0.0317	0.032	0.0315	0.1929	0.080	0.032		
22	0.0312	0.0299	0.028	0.0253	0.1286	0.028	0.0295	0.2126	0.090	0.028		
23	0.0281	0.0269	0.025	0.0226	0.0258	0.024	0.0270	0.2323	0.100	0.025		
24	0.0250	0.0239	0.022	0.0201	0.0230	0.022	0.0250	0.2520	0.125	0.022		
25	0.0219	0.0209	0.020	0.0179	0.0204	0.020	0.0230	0.2756	0.250	0.020		
26	0.0188	0.0179	0.018	0.0159	0.0181	0.018	0.0205	0.2992	0.375	0.018		
27	0.0172	0.0164	0.016	0.0142	0.0173	0.0164	0.0188	0.3228	0.500			

(Continued on page 745)

All Kinds of Steel Tubing for All Kinds of Jobs

B&W Mechanical Tubing is available in all carbon steels, NE alloys, SAE alloys, stainless and corrosion resistant steels.

Finding the right kind of tubing—Seamless or Welded—for each mechanical requirement is greatly simplified when the problem is put up to Babcock & Wilcox. Matching tubes to jobs—finding the steel analysis best suited for each purpose—is a specialty with B&W.

To this end, metallurgists and technicians are continuously searching for better alloys—testing for proper hardness and hardenability—checking yield strengths, elongation, and tensile strengths against service demands. At B&W your problems are considered in the light of experience with an unusually large variety of analyses, many of them available from no other source; first hand knowledge of the fabricating, machining, heat-treating, and other capabilities of steels from simple low carbons to high alloys. Making a complete range of both Seamless and Welded Tubing, B&W is in a position to match tubes to jobs without prejudice toward any type of materials. B&W recommendations are therefore impartial and unbiased.

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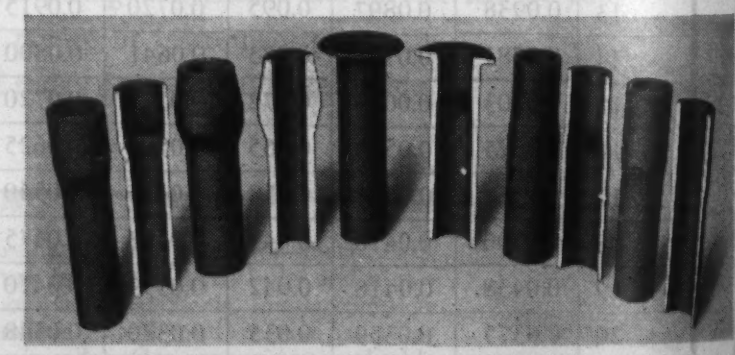
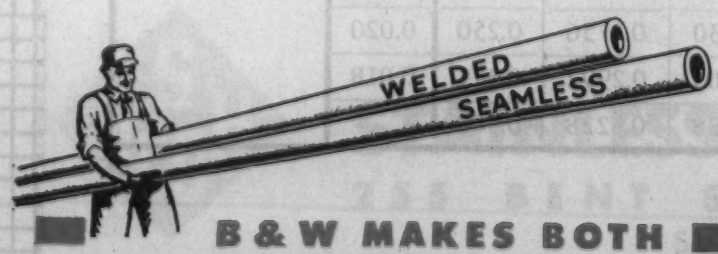


Typical examples of special forms of B&W Mechanical Tubing



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Seamless Tube Division, Beaver Falls, Pa.

TA-1330

Engineering File Facts

NUMBER 76 (Continued)

STANDARD GAGE SIZES

Gage No.	U. S. Standard	Manufacturers' Std. for Sheet Steel	Birmingham or Stubs'	Am. or Brown & Sharpe's	Washburn & Moen	British Standard	London or Old English	Paris or French Gage	Am. Zinc Gage	Am. Std. Preferred Thicknesses	Copper Sheet and Strip Cold Rolled to Weight	
											Wt. per sq. ft. oz.	Theoretical thickness in.
28	0.0156	0.0149	0.014	0.0126	0.0162	0.0148	0.0165	0.3465		0.016		
29	0.0141	0.0135	0.013	0.0113	0.0150	0.0136	0.0155	0.3701		0.014		
30	0.0125	0.0120	0.012	0.0100	0.0140	0.0124	0.0138	0.3937		0.012		
31	0.0109	0.0105	0.010	0.0089	0.0132	0.0116	0.0123			0.011		
32	0.0102	0.0097	0.009	0.0080	0.0128	0.0108	0.0113			0.010		
33	0.00938	0.0090	0.008	0.0071	0.0118	0.0100	0.0103			0.009		
34	0.00859	0.0082	0.007	0.0063	0.0104	0.0092	0.0095			0.008		
35	0.00781	0.0075	0.005	0.0056	0.0095	0.0084	0.0090					
36	0.00703	0.0067	0.004	0.0050	0.0090	0.0076	0.0075			0.007		
37	0.00664	0.0064		0.0045	0.0085	0.0068	0.0065			0.006		
38	0.00625	0.0060		0.0040	0.0080	0.0060	0.0058			0.005		
39				0.0035	0.0075	0.0052	0.0050					
40				0.0031	0.0070	0.0048	0.0045			0.004		
41				0.0028	0.0066	0.0044						
42				0.0025	0.0062	0.0040						
43				0.0022	0.0060	0.0036						
44				0.0020	0.0058	0.0032						
45				0.0018	0.0055	0.0028						
46				0.0016	0.0052	0.0024						
47				0.0014	0.0050	0.0020						
48				0.0012	0.0048	0.0016						
49				0.0011	0.0046	0.0012						
50				0.0010	0.0044	0.0010						

It should be noted in connection with all gages that there is a strong tendency to specify all sheet, strip and wire thicknesses in decimal fractions of an inch rather than in gage numbers.

United States Standard—adopted for sheet iron and steel by act of Congress in 1893. Based upon weight per sq. ft. of material.

Manufacturers' Standard for Sheet Steel—adopted by Am. Iron and Steel Institute. About 4% heavier and thinner than U. S. Standard because based upon steel instead of wrought iron. For steel sheet and strip.

Birmingham or Stubs'—Employed to a limited extent in Great Britain. Used here for seamless tubes of steel and non-ferrous metals. Sometimes applied to sheet copper, strip steel.

American or Brown & Sharpe's—Used for most non-ferrous sheets and wire, and coming into increasing use for ferrous and non-ferrous seamless tubing.

Washburn & Moen—Commonly used in United States for steel and iron wire. Sometimes called U. S. Steel Wire Gage, or Roebling Gage.

British Standard—Legal standard in Great Britain for non-ferrous sheet and for ferrous and non-ferrous wire. Sometimes called Imperial Wire Gage, or New British Standard Gage.

London or Old English—Sometimes used for wire.

Paris or French Gage—French standard for all sheet and wire.

American Zinc Gage—for zinc sheet and plate.

American Standard Preferred Thicknesses—for uncoated thin flat metals. These sizes are based upon the preferred numbers series of the Am. Standards Assn. Similar size ranges for wire are under consideration.

Compiled by Kenneth Rose, Engineering Editor

4 TIMES LONGER LIFE

Eight years' service instead of two, was obtained by a large chemical company through specifying Nickel cast iron in this 8-ton ring. Plain iron used here corroded and eroded ½" per year. This Nickel alloyed iron wears less than ⅛" in the same time.

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In products and applications . . . from a wrench to a railroad . . . records show that a little Nickel goes a long way to lengthen product life, to reduce bulk and deadweight, and to save maintenance costs.

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THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street, New York 5, N.Y.

NUMBER 77
March, 1945

Anti-Friction Bearing Maintenance

Basically, all anti-friction bearings consist of two hardened steel rings, the hardened balls or rollers, and the separator. Variations are common. In the needle-type bearing, the rollers fit directly on the hardened shaft, dispensing with the inner ring and the separator.

In disassembling an anti-friction bearing, the first rule is cleanliness. The bench should be clean, and covered with clean paper; clean, lint-free rags should be used for wiping; tools should be clean, solvents and oils should be clean, and the hands of the operator should be clean. Before removing the bearing, the housing should be freed of loose dirt.

An arbor press or a bearing puller may be used to remove the bearing from the machine. The bearing ring that does the turning is usually tight, although for some types of bearings, *i.e.*, those made with separable parts, both rings are tight fits. Whenever possible, force should be exerted only on the ring that is tight. When a press cannot be used to remove a bearing from a shaft, the shaft may be driven out with a hammer, striking on a soft metal slug placed on the end of the shaft.

Before attempting to inspect the bearing, it should be thoroughly cleaned. Bearings without seals should be washed in petroleum solvents, kerosene, or gasoline, allowing a sufficient soaking time to loosen grease and dirt. Several hours may be required. A small tank and wire baskets are best for soaking, but a clean grease can or bucket may be used.

The bearing should be rotated slowly by hand while washing. Tightly adhering dirt or chips may be removed with a short-bristled brush.

Bearings with removable seals, or with seals or a shield on one side only, may be handled in the same manner as those without seals. Bearings with seals or shields on both sides should not be washed, but should be wiped clean and tested for smooth turning.

The bearing is held so that its axis is vertical and, holding the inner race, the outer race is slowly revolved, observing whether any roughness or sudden stopping occurs. If so, the bearing should be cleaned again. Should the bearing still feel rough or have a catch, separable bearings should receive a more careful examination for the following defects:

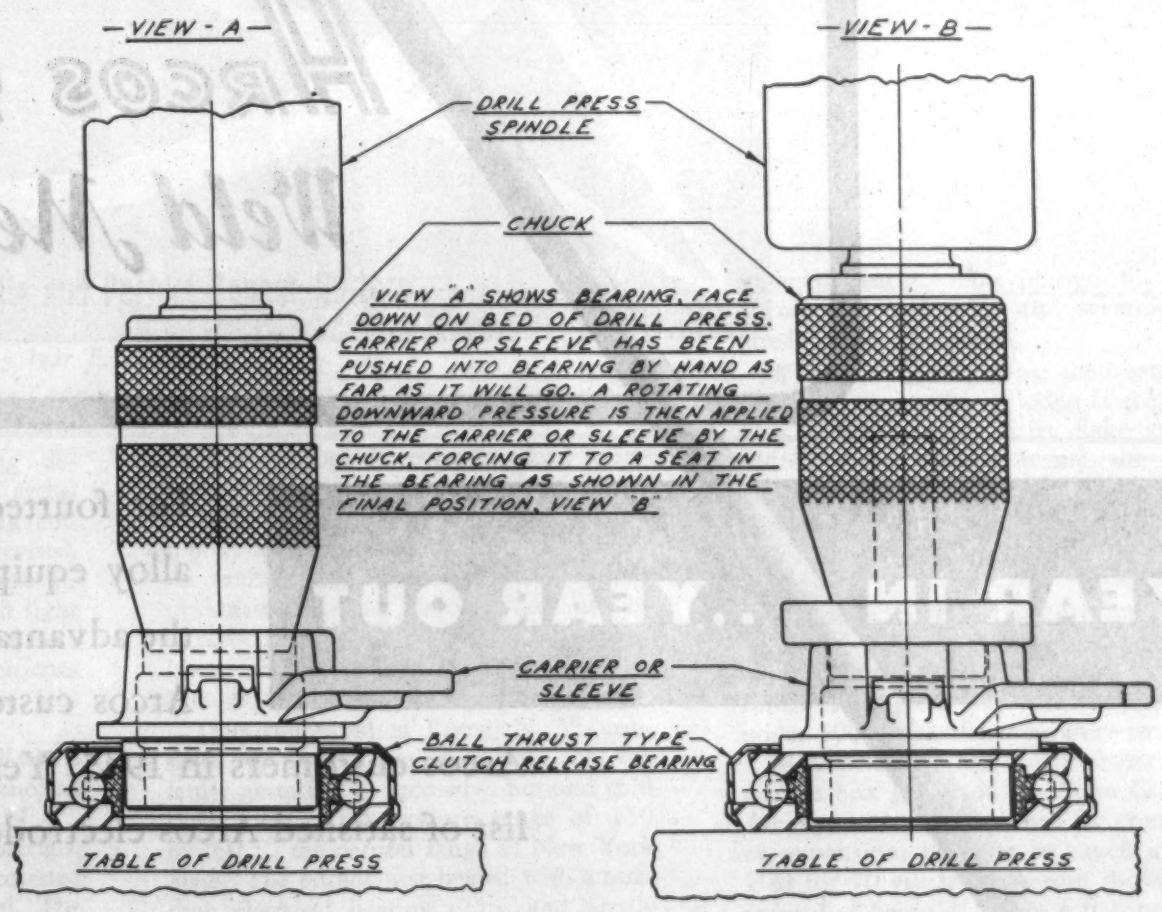
(1) Broken or cracked rings.
(2) Dented seals or shields.
(3) Cracked or broken separators.
(4) Broken or cracked balls or rollers.
(5) Flaked areas on balls, rollers, or raceways.
(6) Damage from overheating, usually indicated by brownish-blue or blue-black color.
(7) Indentations or "Brinelling" of the races.

Any of these defects will make the bearing unfit for further service.

Ball thrust bearings are not spun, but are placed on a firm, clean surface with the flat face down and rotated slowly by exerting even pressure and turning with the palm and heel of the hand. Roughness of the balls or races can be felt during rotation.

After inspection, if the bearing is not to be reassembled immediately, it may be dipped in oil and kept overnight in a tightly covered pan or box. For longer storage a coat of light protective grease should be applied, worked in by rotating the parts, and a greaseproof wrapper applied. A clean box or carton, or an outside wrapping of waterproof paper, will afford protection during storage.

When the bearing is to be remounted, shafts and bearing housings should be thoroughly cleaned. A small amount of oil on the bearing sea eases assembly. The bearing should be pressed on straight and square, applying pressure only on the ring that takes the tight fit. An arbor press or a hammer may be used, observing precautions similar to those for removal of the part.



Large bearings may require heating for assembly. The bearing is warmed in a controlled-temperature oven or in an oil bath to 200 to 250 F., taking care not to exceed the latter heat. When necessary, the shaft may be chilled in dry ice.

Assembly of ball thrust bearings on carriers or sleeves may be best done on a drill press, as shown in the accompanying illustration. The lowest spindle speed should be used. The chuck is closed tight without a drill (as in View A), or, if the chuck diameter is too large or too small, a small shanked pilot may be clamped in the chuck (as in View B).

Prepared from a bulletin of the Engineering Committees, Anti-Friction Bearing Manufacturers' Assn., Inc.

YEAR IN ..YEAR OUT

For fourteen years, fabricators of alloy equipment have recognized the advantages of Arcos electrodes. Arcos customers of 1931 are still Arcos customers in 1945. Year in and year out, the list of satisfied Arcos electrode users becomes larger.

ARCOS

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42 ARCOS GRADES

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Chrome-Nickel and Straight Chrome Electrodes

for Low Alloy Chrome Steels
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for Nickel, Bronze, etc. Alloys
Non-Ferrous Electrodes

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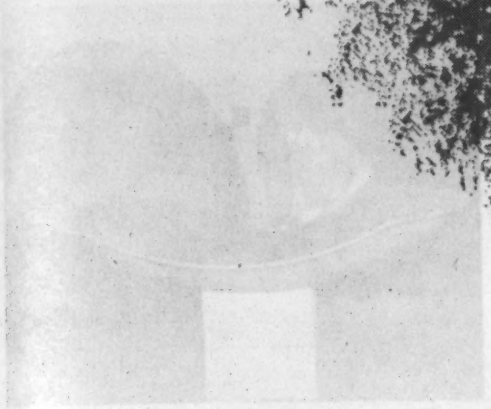
engineering SHOP NOTES



Testing Faulty and Perfect Copper Gutters

by Ivar E. Anderson,
Revere Copper and Brass, Inc.

Apparently standard engineering designs for sheet metal workers and architects, as they regard copper roofing and gutter installations, will have to be revised. It has been common practice to use 16 oz. electrolytic soft copper, but such light copper has badly failed on some notable buildings in actual service and when conditions were duplicated in Revere laboratories.

Thus, roofing and gutter installations in New York State buildings connected with Cornell University at Ithaca, N. Y., repeatedly failed and Government officials, given to cutting down expenses, protested further installations of such material. The copper was wrinkling, buckling and fracturing after only three or four years of service.

Revere assumed responsibility in behalf of the copper and brass industry of finding the cause of failure, as well as a remedy, and taking steps to revise standard specifications. Tests were conducted with box gutters, the most difficult installations to apply. It was found that while some of the faulty installations were due to bad workmanship, chief defects were use of incorrect gage and copper temper. The 16-oz. soft-rolled copper lacked column strength.

Tests conducted at Rome, N. Y., consisted of submitting duplicates of the faulty guttering to successive hot and cold cycles over a temperature range of 150 to 160 F., the natural range in New York State. The author first heated with steam, then electrical heating units, and finally 250-watt heating lamps. He used ten of these on a model gutter 3 ft. long, employing the principle of radiation.

However, the gutter did not absorb enough heat, reflecting heat rays instead. So he darkened the gutter by washing it in a sodium hydroxide solution. Then temperature rose to 400 F., twice as high as needed. Chilling was done with a sprinkling system, fed from water of the Mohawk River.

The final testing installation consisted of 374 heating lamps concentrating on a 65-ft. gutter section. Six minutes of heat cycle duplicated a year's exposure to weather. The first gutter test consisted of two 32-ft. sections separated by a 1-ft. expansion joint, its 8-ft. sheets joined by soldered seams. This started to buckle during the first cycle and severely fractured by the fifteenth.

When using stiffening members, consisting of supporting wooden frame, rosin-sized building paper, with flake graphite added to the wooden frame, the copper didn't start to buckle until the tenth cycle, fracturing at the twentieth. Thus entered recognition of the function of columnar action.

The buckles in the failing gutter were malletted down, the seams were repaired and a stiffening member of 16 oz. cold-rolled strip was applied. It stood up under 500 cycles of temperature treatment.

Meanwhile, it had been observed that a huge box gutter on the State Capitol at Albany, with no allowance for contraction or expansion, had not so much as wrinkled for 70 yr. Investigation showed that, instead of being of 16-oz. soft copper, it is of 34-oz. cold-rolled copper. So the author duplicated in the laboratory this gutter and tested over 500 cycles and it came through perfectly. On the Capitol building the heavier weight metal, though fixed, had absorbed the expansion factor by bowing out without buckling.

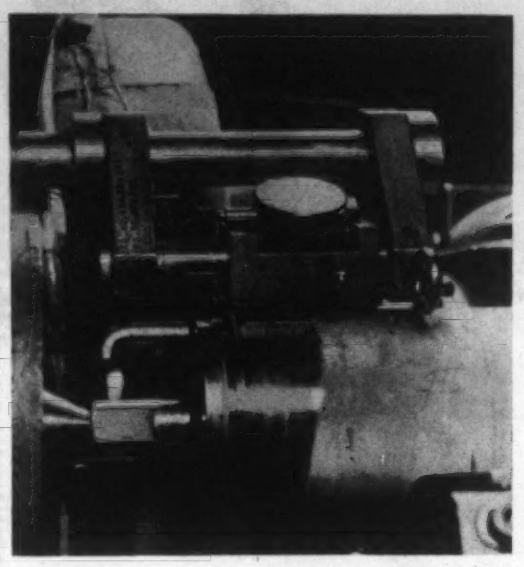
The use of heavier metal for monumental construction was plainly indicated by the tests. They confirmed a survey of faulty gutters on ten State buildings, six failing because of inadequate column strength. Data will be published by Revere as a manual.

The accompanying photo reveals two 65-ft. box gutters during a 6-min. testing cycle under twin rows of 250-watt heating lamps, with temperature change of 160 F.

Carbide Fingers Used on Gages

by John Curtis,
Carboloy Co., Inc.

Use of carbide gage fingers has insured accurate gaging during grinding at a large aircraft engine plant in Detroit, under conditions that would wear steel fingers away so rapidly that the operator would be forced to continually re-set his gage.



The job where these fingers are used (shown here) consists of grinding the O.D. of aircraft cylinder sleeves to extremely close tolerances. The gage fingers—made of Carboloy cemented carbide where they contact the rotating work—are so set that when the gage reads "0" they automatically shut off the machine feed, thereby saving an appreciable amount of time on long production runs.

Since no lubricant can be used on these gage fingers for obvious reasons, it is impractical to employ steel for this purpose since steel would wear away so rapidly that the operator would be forced to continually re-set his gage to maintain accuracy. The Carboloy fingers, however, stand up under these conditions, and are reported to have made this type of gaging fixture practical with a resultant material increase in production.

Centralized Tool Control

by W. E. Ainsworth,
Puget Sound Navy Yard

Advantages of centralized tool control are many, but the most important is greater output by prolonging the life of tools. The central tool shop is the custodian of all loose, hand and portable power tools in the industrial department of the Puget Sound Navy Yard, and is responsible for upkeep, storage, issue and salvage of the tools. Sometimes it even manufactures tools.

Other advantages of central control are that inventory may be held to a minimum, with tools being transferred from one toolroom to another, as required. Moreover, fewer tools are idle.

Such centralization of the tool supply, including grinding and other repairs, enables the departments using the tools to concentrate on production work. Take the pneumatic flat chisel, the most commonly-used in ship construction and repair of any tool. To obtain the best results and maximum uniformity from this chisel, all factors in its manufacture must be under control. All chisels forged from the same bar, heat-treated exactly the same and ground exactly the same, should prove fairly uniform.

In reconditioning chisels by the thousands daily, it was found that the operators, grinding them freehand, regardless of how skillful, were turning out chisels that were not uniform. To overcome this, the yard purchased an automatic chisel grinder, probably the only automatic chisel grinder in use.

With this machine it is only necessary to place the chisel in the gage and press the starting button. When the cycle has been completed the chisel drops from the machine. The setting used will grind from 150 to 180 chisels per hr. After passing through the grinder the tools are given a surface-hardening treatment of the cutting edge in an induction hardening machine, handling 300 per hr.

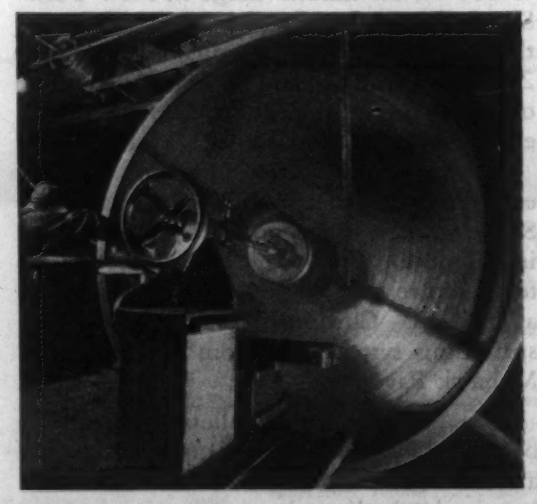
Tools that are in need of grinding are delivered to the central tool shop in special containers, constructed so that the tools may be held in position without injury to cutting edges. Each container is marked with its tool room number and is fitted with a reversible cover, marked "dull" on one side and "sharp" on the reverse side, thus indicating where the tools are to go.

There are several miscellaneous duties of the central tool room. All measuring tools are checked for accuracy after each issue. Goggles, respirators, welder hoods, etc., are sterilized after each issue. Pneumatic tools are cleaned daily. All gear hobs are numbered and recorded in a hob book.

Spinning of Flattened Expanded Steel

by Helen Kupfer,
Milwaukee Metal Spinning Co.

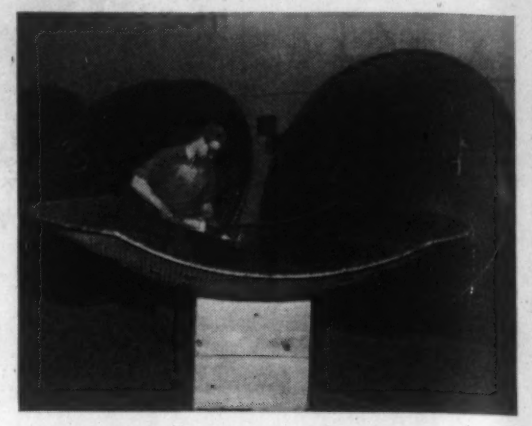
One of the most unusual and difficult jobs to come off the metal spinning lathes at Spincraft (Milwaukee Metal Spinning Co.) is a parabolic antenna of flattened



expanded steel, such as used for safety guards on machinery, metal laths, ornamental work, etc. Spincraft welded two half circles of this expanded steel to make a circle 102 in. in diam.

The maple spinning block alone weighs approximately 2½ tons and is 104 in. in diam., (Fig. 1). While revolving on the lathe at 185 r.p.m., this circle was "dished" or "spun" to the concave block, shaped to the desired parabolic curve.

The spun expanded steel was then trimmed and cut to the shape shown on the customer's blueprint. Then seamless



steel tubing, ¾ in. in diam. and ⅛ in. wall thickness, was welded to the outer edge for strengthening the assembly. All ragged edges were ground off (Fig. 2), and the entire assembly was given a coat of red primer.

The job had hitherto been considered impossible.

Brushing Away Potential Fatigue Failures

by G. O. Rowland,
Osborn Mfg. Co.

The primary cause for failure of as high as 80% of machine parts such as gears, crankshafts, piston rods, valve rods, threaded parts, springs and shafts is stress concentration and progressive fracture, according to engineering studies. Higher speeds of today intensify the problems of repeated or reversed stress, commonly called "fatigue."

This progressive fracture can be reduced, and often eliminated, by power brushing. Failure starts at some point where actual stress is much larger than calculated stress. This high localization of stress is often caused by sharp edges and burrs.

An abrupt change of cross section can be fatal, such as with square shoulders, V-notches, screw threads, burrs, tool marks, sharp edges, scratches, a keyway, or external or internal flaws of the metal.

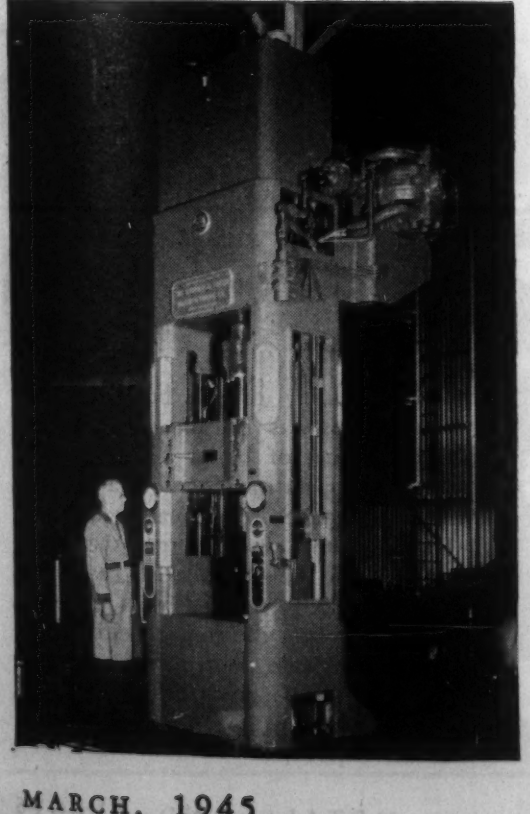
Proper brushing is a proven preventive measure, especially in reducing effects of tool marks, burrs, sharp edges and scratches. Brush blending of surfaces, edges and corners aids materially in limiting stress concentrations. A sharp edge may reduce the endurance limits of a machine part by 50%; a V-notch, by 60%.

Good brushing blends tool and grinding marks and can produce surface smoothness of 8 micro inches where necessary. It promotes excellent stress distribution while other fast methods frequently create secondary defects.

THIS HELIXAUST MANIFOLD for diesel engines, fabricated by Dayton Fabricated Steel Co., increases engine efficiency by reducing back pressure. 3/16" fillet welds are made with Murex Type FHP Electrodes, selected because of their excellent "hot" rod characteristics. All-position Vertex rods are used for the circumferential butt welds.

INSPECTING MUREX ELECTRODES. Careful production control—from raw materials to packing—is one of the reasons for uniform results with Murex.

THE DRAFT SILL ASSEMBLY of a freight car is being welded with Murex Electrodes in the plant of Pullman-Standard Car Manufacturing Company. Downhand rods are used because they are ideal for long, horizontal fillets and deposit sound X-ray clean weld metal at a rapid rate.



ARC WELDING, with Murex Electrodes, speeds the fab rication of cartridge case drawing presses for The Hydraulic Press Manufacturing Company. Instead of using steel castings throughout (the conventional method), the cylinder, slide and numerous other parts are arc welded. Vital production time is saved and the company is not dependent on outside casting facilities. Positioning equipment permits the use of "hot," downhand Murex Electrodes, resulting in fast deposition, low cost and sound, X-ray clean welds.

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"Watchdog" Laboratory for Plating

by L. Sanders,
Glenn L. Martin Co.

A special "watchdog" laboratory that controls constantly anodizing, plating, and other processing solutions pays bid dividends in saved man-hours and uniform high quality at the Glenn L. Martin Co., Baltimore. The plating room has been placed on a highly standardized production basis despite wide variety of work

and many semi-skilled employees, all of whom are relieved of all worries about varying times and procedures to meet changes in the bath.

The laboratory is in the plating room as an integral part. It stands watch over the 40 or more chemical baths for processing a wide range of parts made of various metals and alloys to withstand corrosion. Samples are taken from each tank daily and analyzed for, say, PH, current density, total chromic acid, free chromic acid, specific gravity, etc., in case of anodizing baths; and for the amount of metal in solution, free cyanide and similar characteristics, in case of plating baths.

The laboratory also runs sample parts through the various baths each day for visual inspection of the film or metal deposit.

A "Goggle Cart," operated by girls skilled in the maintenance of safety glasses, has reduced eye injuries 75% at Center Line Ordnance Div., Westinghouse. Taken directly to the worker's bench, the cart is stocked with lenses, bows, adjustment screws and related items to keep safety glasses ship shape.

—Helen Liberman, Westinghouse

Repairing Cracked Castings by Metallizing

by Jos. S. Plumeau, Motor Equipment Div., Dept. of Sanitation, New York

The repairing of cracked cylinder heads and blocks of automotive equipment by metallizing may suggest a similar process in related fields and applications. In our case, most of the cracks are caused by freezing of cooling water, or placing of cold water in an overheated engine's cooling system. A typical cast iron head weighs 42 lb., is 10 x 16½ x 2½ in. in size, and costs $17.50 to replace—when you can get replacements.

Our former repair method was as follows: We removed the head, cleaned, heated in a pre-heat furnace, then gas-welded with a cast iron rod, while covered with an asbestos or metal canopy to protect from draughts. It was allowed to cool slowly. Then it was placed in a planer to refinish the under side, which invariably would be distorted from welding heat. The cost was $12, not including finishing, machining, or allowance for overhead. At least 10 hr. was needed, a large share cooling time. With an engine block, four days was needed, since valves and studs had to be removed. Moreover, the block usually had to be reground and fitted with new pistons, rings and wrist pins.

By the metallizing method, the head is cleaned of grease, dirt and carbon and blasted with angular steel grit for 3 in. on each side of the crack, with the idea of tapering the sprayed metal to a very thin coating at the edges, hence eliminating any chance of its later "lifting" off.

Next we metallize it, spraying from an iron wire in the spray gun, going over and over the crack and 2 in. on each side of the crack. Over the crack the thickness of the sprayed metal becomes about 0.050 in., tapering to a much thinner coating at the edges. If the crack is very long, one pauses from time to time to allow for cooling so that but little distortion will occur.

Often the head or block can be metallized without removal from the truck, when it becomes only a 2 hr. job. When doing a metallizing job in the chassis, a canvas tarpaulin is placed around the engine so that no grit will be lost or enter the engine. We have metal sprayed many badly cracked blocks in the chassis—even those with long under-the-hood cracks.

We apply a 60-lb. hydrostatic pressure test (air and water) as a final test for strength and porosity, as against 20-lb. tests used for our former welded jobs. After the test, the head of the block is coated with engine paint and is again ready for use. Generally, the time is only one-tenth that of the gas welding method.

Here is a tricky little principle that may have many useful applications. Many ships carry apparatus for distilling sea water into fresh water. A certain still built by Heat Transfer Products, Inc. has a clever patented method of eliminating the brittle salt scale that accumulates. Called the self-descaling evaporator, the tubing is of admiralty brass, with a strip of Monel silver brazed along one of its sides. When heat is applied the brass tubing expands, but the stretch is retarded on one side by the lower thermal expansion of the Monel strip. Hence, the tubing curves outward as temperature rises. Contraction on cooling causes it to re-straighten. This almost constant flexing cracks off the scale.

—"Mechanical Topics," International Nickel Co., Inc.

Cleaning Stubborn Glass Chemical Apparatus

by Otha K. Coleman, University of Georgia

It is hard to keep laboratory apparatus clean, especially the glass trivia such as test tubes, funnels, crucibles, flasks, glass rod, tubing, etc., even with abrasive soaps, dichromate cleaning solution and trisodium phosphate. Try this sometime.

Place the dirty apparatus in an appropriately-sized refrigerator dish (9 in. long, 4 in. wide and 3 in. deep), covered with a tightly-fitting lid, partly filled with recovered alcohol or other good solvent, or combination of solvents. Keep the dish near the sink as a convenient depository for waste solvents.

Remove apparatus periodically from the solvent bath and place in a solution of trisodium phosphate, keeping it there overnight, or longer. Remove from the bath and rinse. By now it may be drained clean—at the worst, a minimum amount of scrubbing is needed.

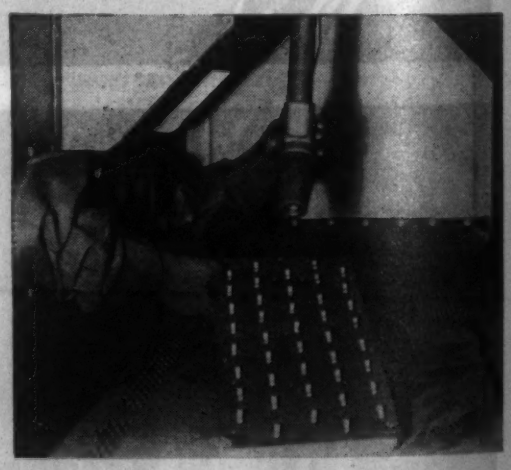
(From "Witcombings" of Witco Chemical Co.)

Plastic Sand Blast Cabinet

by Camilla McComber, Newell-Emmett Co.

In sandblast cabinets used by the Ithaca Gun Co. the force of the steel grit, driven over the parts in the cabinet under 90 lb. pressure, quickly wore through the boiler plate, used as protective covering, necessitating replacement every 3 or 4 hr.

It was a different story when the boiler plate was replaced with a sheet of "compar," a flexible rubber-like plastic developed by Resistoflex Corp., Belleville, N. J.,



fastened securely to the bottom of the cabinet. This has resistance to abrasion 250 times that of boiler plate, allowing continuous operation for several months without stoppages for replacement.

Likewise, the wooden tray that holds small parts to be sandblasted (as shown in the photo) is covered with the same material. Though the tray is held directly beneath the nozzle pouring out steel grit, the compar shows no wear after months of use.

Metal-Working Industries

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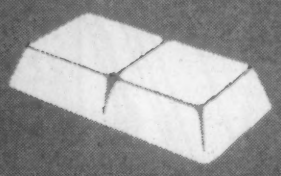

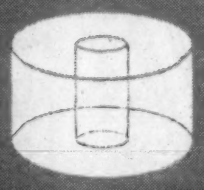

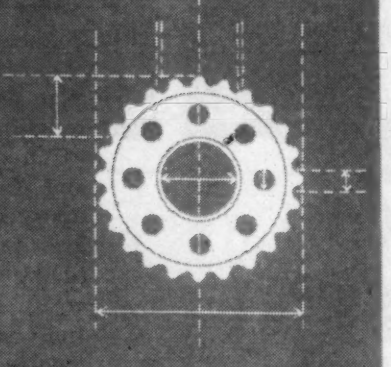

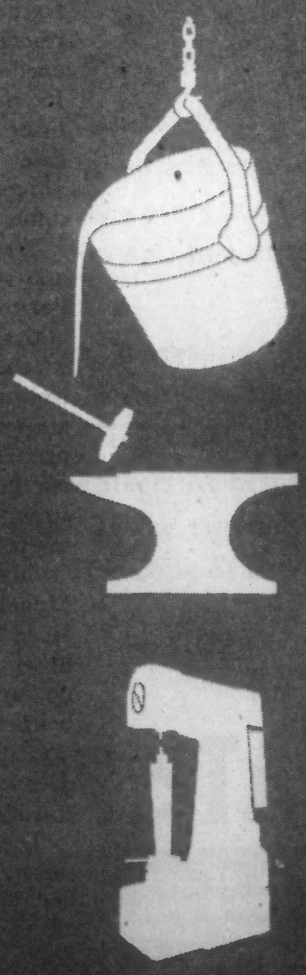

ENGINEERING DIGEST

A selection of outstanding articles on engineering materials and processing methods

MATERIALS and DESIGN

Metals and Alloys

Properties of Nickel Alloys 758
Properties of Centrifugally Cast Steel 760
18-8 Stainless for Forming 762
N.E. Steels for Forgings 764
Creep Properties of Aluminum 766

Nonmetallic Materials

Use of Plasticizers 768
Wartime Fabric Developments 770
Flame Resistance of Plastics 772
Exposure Resistance of Cellulose Esters 774

General Product Design

Fretting Corrosion 776
Painting Plastics 776
Production Considerations in Design 778
Fatigue Strength of Diesel Crankshafts 780
Piston Design 784

METHODS and PROCESSES

Melting and Casting

Inhibitors for Magnesium Casting 786
Pressure Ferrous Castings 788
Electrochemistry of Magnesium 790
Blast Furnace Tuyeres 792

Fabrication and Treatment

Deep Drawing Technique 794
Fusion-Welded Boilers 796
New Plastics Forming Technique 798
Forging Light Alloy Pistons 800
Electrostatic Spraying of Enamel 802
Electrodeposition for Repair 804
Pressure Welding 806
Precision Broaching 808
New Contour Developer 810
Continuous Injection Molding of Plastics 812

Testing and Inspection

Fatigue Testing 814
Control of Steel Forgings for Aircraft 816
Immersion Thermocouple 818
Taper Measuring Device 820
Measuring Metal Thicknesses Radiographically 822
Testing Aluminum Rivet Wire 824

MATERIALS AND DESIGN

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Engineering properties and applications of carbon, alloy and stainless steels, irons and nonferrous metals and alloys. Selection and evaluation of metallic materials for engineering service. New alloys and modifications.

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Properties of Nickel Alloys

Condensed from a Paper of the American Society of Mechanical Engineers

While nearly 2300 compositions containing 1% or more nickel are known and used, only those containing more than 50% nickel are considered here. These are classified in six groups: (1) Nickel—99.4 to 95.2% nickel, and manganese to 4.5%. (2) Nickel-copper—approximately two-thirds nickel and one-third copper. (3) Nickel-silicon—nickel 85% and silicon 10% (cast only). (4) Nickel-chromium-iron—nickel 78.5 to 60%, chromium 13 to 18%, iron 6 to 24%. (5) Nickel-molybdenum-iron—nickel 60 to 53%, molybdenum 18 to 32%, iron 6 to 22%. (6) Nickel-chromium-molybdenum-iron—nickel 60 to 51%, chromium 17 to 22%, molybdenum 5 to 19%, iron 6 to 8%.

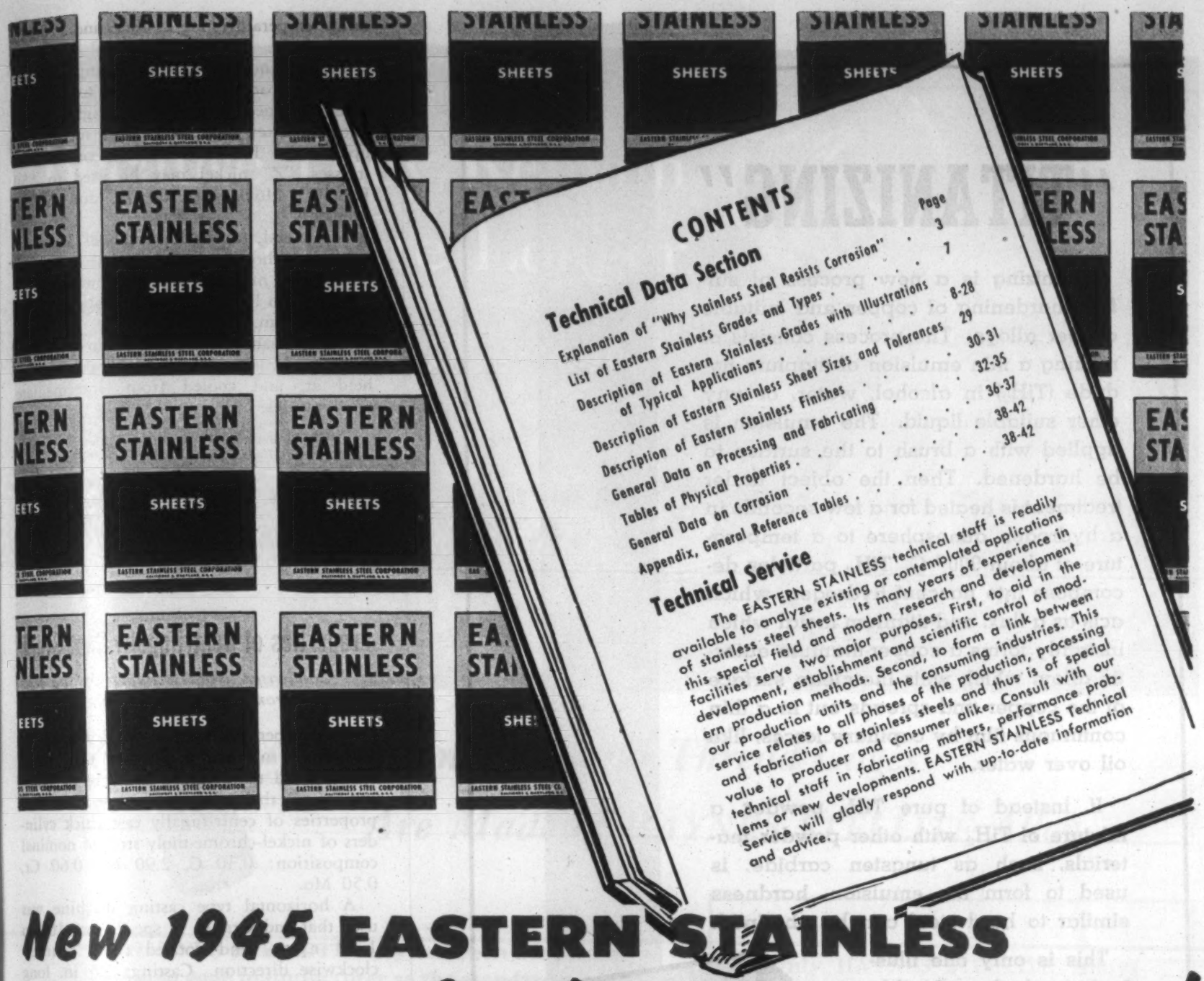
Both wrought and cast forms of the high-nickel alloys have good strength and toughness, and show high ratios of strength to ductility in all conditions of mechanical and thermal treatments. Compressive tests upon six high-nickel materials gave progressive plastic deformation up to the limit of the machine at 175,000 p.s.i. (original area). Average increases of 20% in area and decreases of 15% in length were reported.

Tension impact specimens gave clean fractures in every case. In torsion impact, fractures occurred only with the age-hardened "K" Monel and "Z" nickel specimens. In the hot-rolled and cold-drawn conditions of all specimens by reducing minimum area 75% were not successful. Values ranged from 75 to 180 ft.-lb., depending upon the condition of the alloy.

Nickel can contribute increased strength and resistance to oxidation at elevated temperatures to both ferrous and non-ferrous alloys, and is especially useful in the former. Mechanical properties used in evaluating limiting temperatures for useful service are (1) short-time, high-temperature tensile properties; (2) hot-bend tests; (3) creep strength; (4) high-temperature impact strength; (5) endurance limit at elevated temperatures; and (6) hot hardness.

Strength factors of nickel, Monel, "K" Monel and inconel increase as the temperature is lowered. Elongation increases to a lesser extent, and reduction of area shows no appreciable change. Low-temperature brittleness does not develop, and there is no appreciable loss in impact strength even when the tensile strength increases considerably.

The 80-20 and 60-15 type nickel-chromium alloys are the only ones that have been developed particularly for long-lived electrical heating units. Maximum oper-



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If, instead of pure TiH_2 powder, a mixture of TiH_2 with other powder materials, such as tungsten carbide, is used to form the emulsion, hardness similar to hard steel can be obtained.

This is only one illustration of the possible uses of TiH_2, which also can be used with perfect safety and efficiency in a number of other metallurgical applications.

We shall be glad to send additional information to anyone interested in using TiH_2.

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In general, fabrication methods are more similar to those used for steel than for the non-ferrous metals. They work-harden more rapidly than low-carbon steel, copper, brass, or aluminum.

Nickel materials are soft when quenched from high temperatures, and hard when held at, and cooled from, intermediate temperatures.

—B. B. Betty & W. A. Mudge. *Am. Soc. Mech. Engrs*, paper, Dec. 1944 meeting, 7 pages.

Properties of Centrifugally Cast Steel

Condensed from a Paper of the Iron and Steel Institute

This paper deals with the influence of variations in casting temperature, mold speed, mold temperature and rate of pouring upon the structure, segregation and properties of centrifugally cast thick cylinders of nickel-chrome-moly steel of nominal composition: 0.30 C, 2.90 Ni, 0.60 Cr, 0.50 Mo.

A horizontal type casting machine was used that had a range in speed from 100 to 1700 r.p.m., and rotated in a counter-clockwise direction. Castings 7.5 in. long and 6.4 in. outside diam. were made from 60 to 70 lb. of metal melted in a gas-fired crucible furnace. The castings were taken from the mold at red heat and slowly cooled from about 1200 C. (2190 F.).

Speeds studied were 450, 650, 1000, 1450 and 1700 r.p.m. Pouring temperatures were varied from 1510 to 1590 C. (2750 to 2900 F.), and the pouring times from 30 sec. to less than 12 sec.

In varying the above, three definite types of structures were obtained. Type 1 has three sharply defined zones, the outside composed of a thin layer of chill crystals, the middle composed mainly of columnar crystals coarser than those in the outer zone, and the third of equi-axial crystals.

Type 1 is associated with splashing in the mold during casting, and with low mold speeds, fast pouring and high casting temperature. The conditions which favor type 2 structure appear to be freedom from vibration, high casting temperature, and slow pouring. Marked vibration during solidification is essential for formation of type 3 structure.

The influence of the casting conditions cannot depend upon any one variable, for each to some extent depends upon the other, but may be generalized approximately in the following manner: Mold speed can cause the formation of any of the three types of structure. Low speeds, 450 r.p.m. and 1700 r.p.m., generally cause type 1

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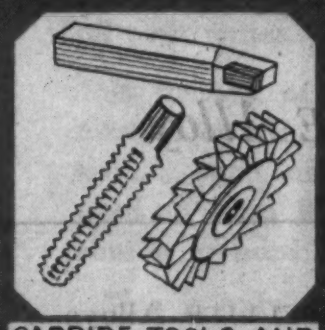

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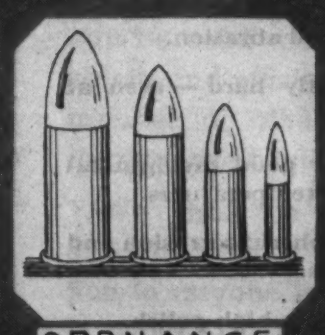

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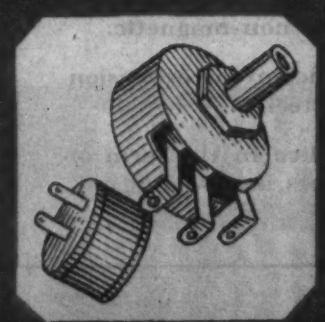

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structure. Medium mold speeds generally caused formation of type 2 structure. High speed, 1450 r.p.m. and 1700 r.p.m., where considerable mold vibration was present, caused type 3 banding.

Casting temperature affects structures generally in the following manner: Raising the temperature favors type 1, hinders type 3, and increases size of primary crystals. The effect of rate of pouring favors the formation of type 1 and type 3.

Because of the decided effect of vibration, its characteristics were investigated. By means of photographing a white card marked with rings attached to the door plate while in motion, the amplitude of the vibration was noted. The maximum amplitude of the vibration slightly exceeded $\pm 1/8$ in. It is to be noted that plain carbon steel, cast iron and many non-ferrous alloys exhibit the same characteristics, and that the formation of peculiarities in structure is not confined to steel alone.

Cracks appear radially due to high mold speeds and rapid pouring. It is believed that these cracks are formed in the early stages of solidification and are due to centrifugal force promoting circumferential tensile stresses sufficiently high to crack the shell after it has contracted from the mold. High pouring rates increase the quantity of liquid in a mold at a given time and thus increase the centrifugal force.

—L. Northcott & D. McLean. *Iron & Steel Inst.* paper, Nov. 1944, 14 pp.

18-8 Stainless for Forming

Condensed from "The Iron Age"

The Ryan Aeronautical Co. recently undertook a study of the formability of stainless steel, one of the few metals suitable for aircraft exhaust manifold systems.

Three groups of stainless steels were tested. One was in the annealed condition in which the sheet undergoes a stretcher levelling operation for removal of waves and buckles resulting from final annealing at the mill. A second group was in the annealed condition without the stretcher levelling operation, and the third contained samples in the work-hardened condition.

Specimens were mounted in cross-section, polished and etched. Examination showed that group 1 contained the largest grain size, group 2 slightly smaller grains, and group 3 the smallest.

An 18-8 type stainless steel of high nickel content will have better forming properties than one of low nickel content. Likewise, high-nickel austenitic stainless will absorb more work than low nickel compositions. For good forming properties, 18-8-type stainless with a nickel content of 11 to 12% is better than one of 8%.

There is evidence to show that carbon, manganese, columbium and titanium have a bearing on forming characteristics. A gain in magnetic permeability of 18-8 stainless as a result of cold work appears to be a function of the nickel-chromium ratio,

IN FORGINGS You get MAXIMUM METAL QUALITY

Forging concentrates grain structure and fibre-like flow lines at points of greatest shock and stress and develops the utmost strength and toughness which a specific metal affords.

7 ADVANTAGES Forgings Offer

1. High tensile and impact strength obtained through concentration of grain structure and fibre-like flow lines.
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5. Forgings facilitate rapid assembly through a welding adaptability of widest range.
6. Forgings reduce accidents to men and machines; provide a greater margin of safety.
7. Forgings can take it; maximum strength and toughness through a concentration of fibre-like flow line structure at points of greatest shock and stress.

● When you have to sell again to get an order you may find, as others have in the past, that selling against a product fortified with the qualities of forgings is both difficult and costly. Avoid the risk of a decline in preference for your product, which may occur and continue unnoticed, while another product establishes its ability to out-perform your product. Dependable performance is assured by the high tensile and impact strength, toughness and high fatigue resistance of forgings —qualities which are obtained by forging metal in closed impression dies, which process directions the fibre-like flow lines to meet specific service conditions.

Many manufacturers have found by rechecking highly stressed parts, as well as simple levers, against the seven advantages that forgings offer, opportunities to improve their product; to lessen weight; to reduce cost, to speed up assembly. A recheck of the parts you require may reveal unusual benefits which have been overlooked or neglected. Consult a forging engineer connected with your source of supply. His broad experience will be helpful to you in obtaining all the advantages that forgings offer you.

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TOOL STEELS • DRILL ROD • COLD ROLLED STRIP STEEL

and this gain appears to be associated with directional characteristics.

Results of tests showed that dead soft 18-8 material is inferior to 18-10 steel in ease of processing. It was also established that differences in percentage of certain alloying elements have a bearing on loss of ductility and harmful change in grain structure on cold working.

Nearly all failures on exhaust manifolds can be corrected by change in design, as the failures could not be directly attributed to defective material, faulty welding, or other fabrication procedure. A survey of research work showed that the creep strength of type No. 347 columbium-stabilized stainless steel is 20 to 30% greater at 1100 F. than that of type No. 321, titanium-stabilized stainless.

A comparison of these two types of steels showed that columbium-stabilized steel welded parts can be used safely without a stabilizing heat treatment, whereas titanium-stabilized steel should be heat treated. It was found that titanium-stabilized steel was superior in ductility to the columbium product in ductility. No. 347, although slightly inferior to No. 321, is entirely satisfactory.

Also, it was determined that a finish equal to a 2 D (dull cold rolled) was the best for use in drop hammer forming operations. A high nickel-chromium ratio allows for a ductile metal. If the nickel content remains about 10.5%, the metal is ductile and trouble free.

—Wilson G. Hubbell. *Iron Age*, Vol. 154, Dec. 7, 1944, pp. 78-82.

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PLANT: BARBERTON, OHIO

N. E. Steels For Forgings

Condensed from "Metal Progress"

Due to service conditions involved, primary interest in N.E. forging steels has been centered in notch toughness and fatigue resistance, particularly in alternating torsion. Special emphasis has been placed on variations of properties in forgings of such size that normalizing and tempering is the only practical method of heat treatment.

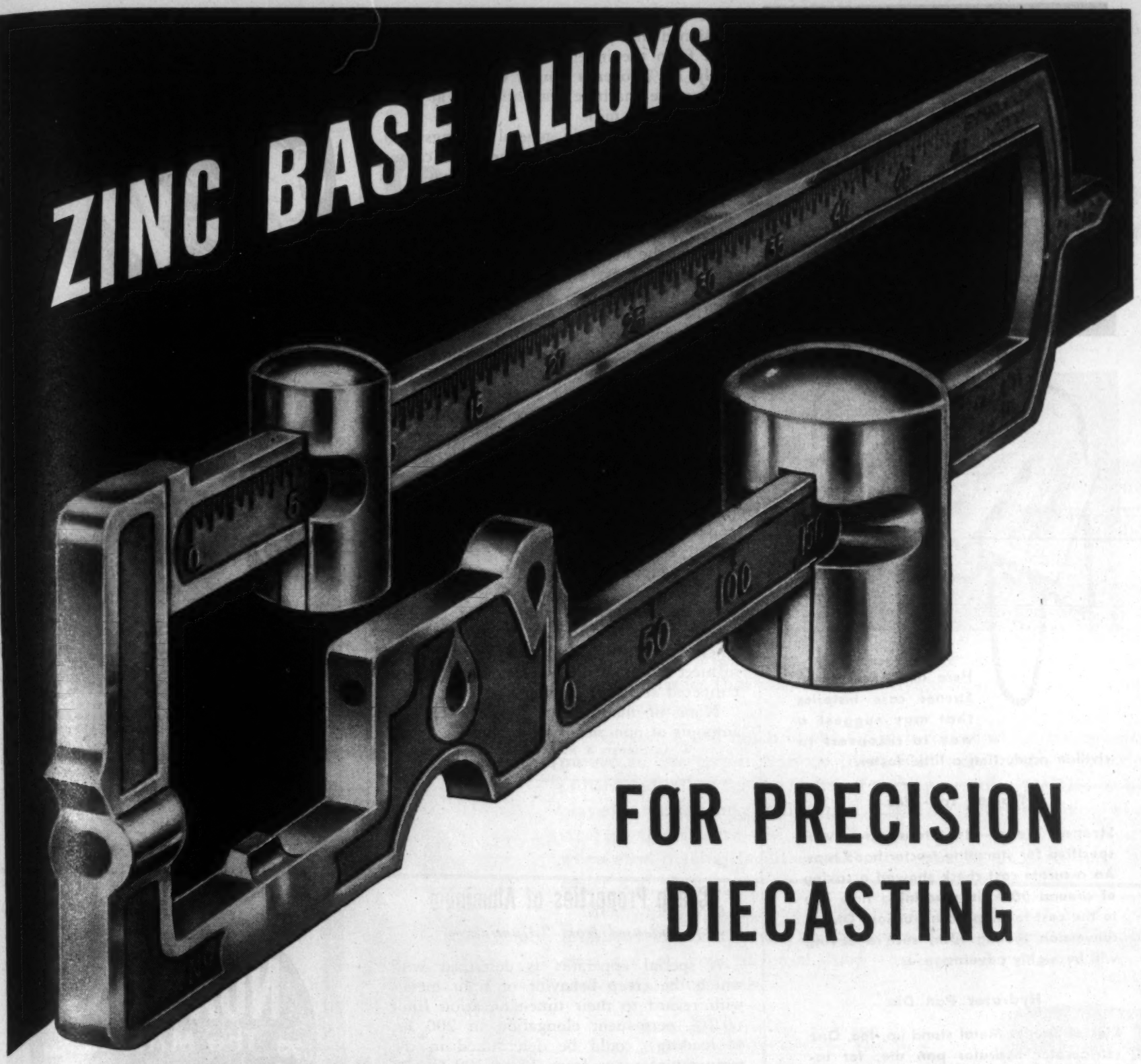
36 steels representing the following 10 grades are being investigated: 8339, 8442, 8630, 8739, 8744, 8749, 8949, 9445, and 9450. Sizes range from 1 in. to 14 in. in diam. Forgings were normalized in full section and tempered in as large sections as practicable.

Tests include determination of static tensile and torsional properties, Charpy impact value, hardness and fatigue resistance in rotating flexure, and alternating torsion. Hardenability was determined by means of end-quench tests.

Temperature-expansion curves were obtained for representative steels. Tension tests were made of standard 0.505-in. threaded-end specimens. Static torsion tests were made of 0.75-in. diam. specimens. Endurance tests in alternating torsion were also made.

Fatigue tests in flexure were made with the rotating cantilever type of specimen.

ZINC BASE ALLOYS



FOR PRECISION DIECASTING

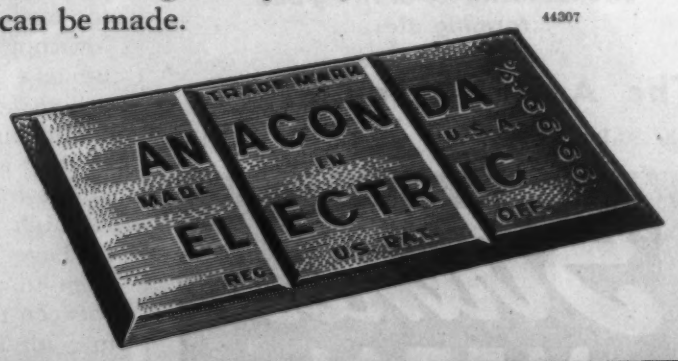
The beam and poises of the Office Clinic Scale as manufactured by the Continental Scale Corporation of Chicago are composed of diecast parts.

A zinc base alloy supplies the ruggedness and accuracy demanded of these parts which must maintain unvarying precision throughout a long service life. When cast, these parts are ready for masking and plating after a minimum of surface preparation.

Of all the commonly used diecast metals, zinc base alloys are easiest to cast and most widely used. They allow the parts designer greater freedom as to size of part, intricacy of shape and complexity of detail. Zinc base alloys also permit thinner cross sections with minimum warpage.

An important point to remember about zinc base alloys is the factor of quality. It depends to a great extent upon the purity of the zinc used. Anaconda Electric—guaranteed 99.99+ percent pure—provides an always dependable base metal from which the highest quality zinc base diecastings can be made.

44307



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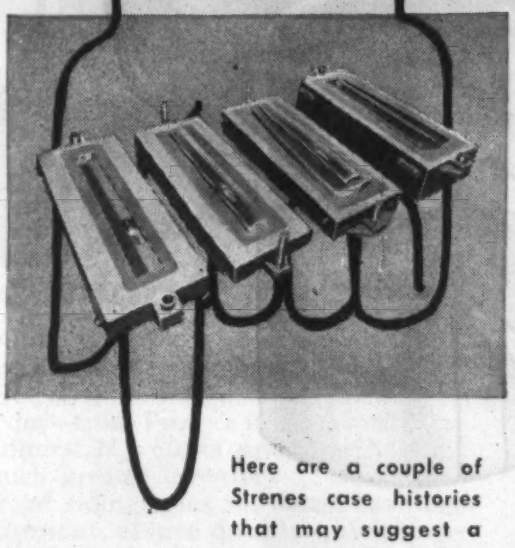
STRENES METAL POINTS THE WAY



Here are a couple of Strenes case histories that may suggest a way to reconvert to civilian production a little faster.

Tractor Top-Dies

Strenes Metal—cast-to-shape—was specified for stamping tractor hood tops. An accurate cost check showed a saving of around 50% in machining time due to the cast-to-shape construction. On reconversion tooling rush, such a saving will be highly advantageous.

Hydrator Pan Die

Dies of Strenes Metal stand up, too. One refrigerator hydrator pan die, for instance, stamped 2,000,000 parts with a 3½" draw out of .50 material. And, due to the self-lubricating property of the metal, stoning and polishing operations were virtually unnecessary.

Both for civilian and war products, Strenes Metal has been a definite help on many tooling programs. Facts and figures on request. Write today.

Strenes Metal for drawing and forming dies.

The Advance Foundry Co.
100 PARNELL ST. DAYTON 3, OHIO

Strenes METAL

The test length is conically tapered and so designed that the maximum stress is ¾ in. out from the inner fillet, and stress varies only 1.5% over a length of 1.5 in. The endurance machine was operated at 1450 rotations per min.

Tests show that in general forgings 8 in. in diam. made of steels of the lower carbon ranges can be normalized and drawn so as to conform to requirements of class An, and those of higher carbon ranges of class HG. There are marginal cases, and for some of the steels specification requirements can be met by adjusting the tempering temperature.

The average endurance ratio for 20 steels in rotating flexure is 0.43, and the corresponding ratio in alternating torsion 0.29. In normalized and tempered steels, best endurance ratios range from 0.44 to 0.47. In general, good endurance ratios followed 1300 F. tempering.

NE steels of the 8000 series offer much promise as alternates for forgings, classes An and HG, of navy specification 49s2. Of the less hardenable steels, NE 8740 is a good representative, of greater hardenability NE 8740.

NE 9445 and 9450 are less satisfactory and failed to meet An or HG requirements when normalized and tempered at 1200 F. However, NE 9445 meets An requirements when tempered at 1300 F. NE 9450 failed to meet requirements when normalized and tempered at 1200 or 1300 F.

None of the samples showed excessive amounts of non-metallic inclusions.

—W. C. Stewart & R. E. Wiley. *Metal Progress*, Vol. 46, Dec. 1944, pp. 1258-1262.

Creep Properties of Aluminum

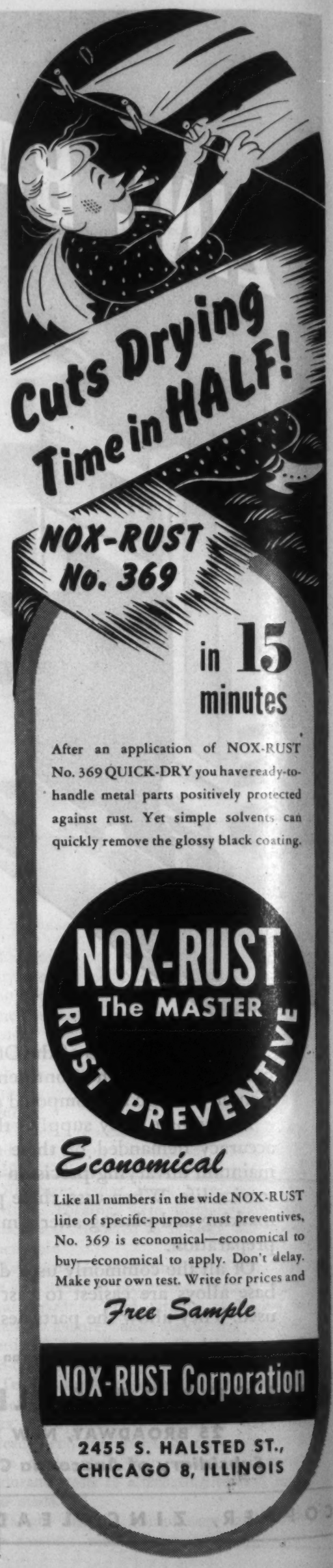
Condensed from "Aluminium"

A special apparatus is described with which the creep behavior of light metals with regard to their time-elongation limit (0.2% permanent elongation in 200 hr. of loading) could be determined in the temperature range from 25 to 300 C (77 to 570 F.). The investigated materials were 5 alloys of the type Al-Cu-Mg (DIN 1713), 3 Al-Zn-Mg alloys, and one Al-Cu-Zn-Mg alloy.

The Al-Zn-Mg alloys have (after hot-precipitation hardening) the best mechanical properties up to 80 C (175 F.). At higher temperatures, however, the Al-Cu-Mg alloys are by far superior. Even with reduced copper content (to about 3%) they showed the same good creep strength for medium and higher temperatures. The low-copper alloys, however, could not be brought by hot-precipitation hardening to a high cold-elongation limit.

The time-elongation limit of an Al-Zn-Cu-Mg alloy was between the scattering ranges found for Al-Zn-Mg and Al-Cu-Mg. At high temperatures, a fine grain seems to have a harmful effect on the creep strength. A relation could be established between the elongation velocity in the 25th to 35th hr. and the load at which 0.2% permanent elongation is reached.

—H. Adenstedt. *Aluminium*, Vol. 25, Jan. 1943, pp. 13-19.



Yesterday's toy...

Today's weapon

When you were a kid and you watched your Fourth-of-July rocket hurtling into the night sky, you never realized that you were firing a potential weapon of the future. Yet at this very moment great salvos of rocket projectiles are zooming at the enemy from landing craft, fighter planes, and other types of rocket-launchers.

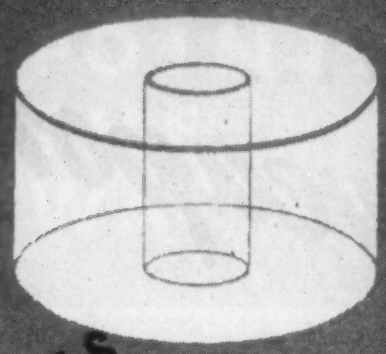
Here at Bethlehem are many workers who, as youngsters, braced their rockets on crates or stones and watched them swish upward, leaving behind a trail of yellow fire. Now, as men, they are helping to produce the steel that is vitally needed for greater and deadlier rockets—missiles that pack a destructive wallop in aerial, sea, and land operations.

You have heard much of the 4.5-inch rocket which has recently proved so effective in various theatres of war. In the production of bars and billets for the bodies of these projectiles, Bethlehem has played a particularly active part. Yet the time is coming when steel of this nature will again be devoted to peaceful pursuits; when steel-making facilities will once more be used to make life easier and pleasanter.

Meanwhile, you are cordially invited to talk over your steel problems with Bethlehem metallurgists. Their services and experience are at your disposal—now—on questions involving both carbon and alloy steels.

BETHLEHEM STEEL CO., Bethlehem, Pa.
Bethlehem Steel Export Corp., New York City

BETHLEHEM STEEL



AND DESIGN

TERIALS

NONMETALLIC MATERIALS

Design-uses of plastics, plywood, fibre, glass, rubber, ceramics, etc. as engineering materials. Composite metal-nonmetal combinations. New types and forms of nonmetallic materials.

Use of Plasticizers

Condensed from "Plastics"

Plasticizers are usually non-volatile organic liquids or low-melting solids that tend to render plastics of high molecular weight, relatively hard, brittle, and intractable, into thermoplastic, flexible, workable masses at room or working temperatures. Investigations indicate that plasticizers act somewhat in the manner of lubricating agents upon the molecules with which they come in contact.

In order to be effective, plasticizers must possess certain properties, of which high boiling range, low volatility, stability to light and heat, good solvent properties, good dielectric properties, increased fire resistance, sharpening of softening point, low temperature flexibility, increased tensile strength, water, oil and chemical resistance, and good compatibility with resins are the most important. No one plasticizer possesses all of these properties, and one plasticizer must sometimes be supplemented with another to obtain the desired effect.

The characteristics desired in the finished product are determining factors in deciding upon the plasticizer and fixing upon the concentration to be used. This may range from 15 to 45%. With cellulose acetate plastics, the concentration may vary from 20 to 35% to give toughness and good structural formation at temperatures suitable for injection molding without causing decomposition.

A concentration of about 30% gives good rubber-like properties to vinyl resins. Plasticizers like tricresyl phosphate impart good fire resistance, and concentration is determined by the resin used.

Plasticizers may be classified as solvents and extenders, and these further subdivided into those of low and of high volatility. Solvent plasticizers are those conferring toughness and somewhat poor cold flow characteristics on the film former, for which they are good solvents. Those giving high tensile strength, greater rigidity and less shock strength because they are nearer the point of insolubility are known as extender plasticizers. They act more or less as colloidal agents. If readily lost from the product, they are said to be of high volatility.

If properly compounded and formulated, materials which of themselves are not sufficiently soluble to form a phase with the plastics can be brought into solution by means of good solvent plasticizers. Many properties other than mechanical influence selection. Flexibility, hardness and toughness are requisites for lacquer films, but at the same time they must possess good surface adherence.

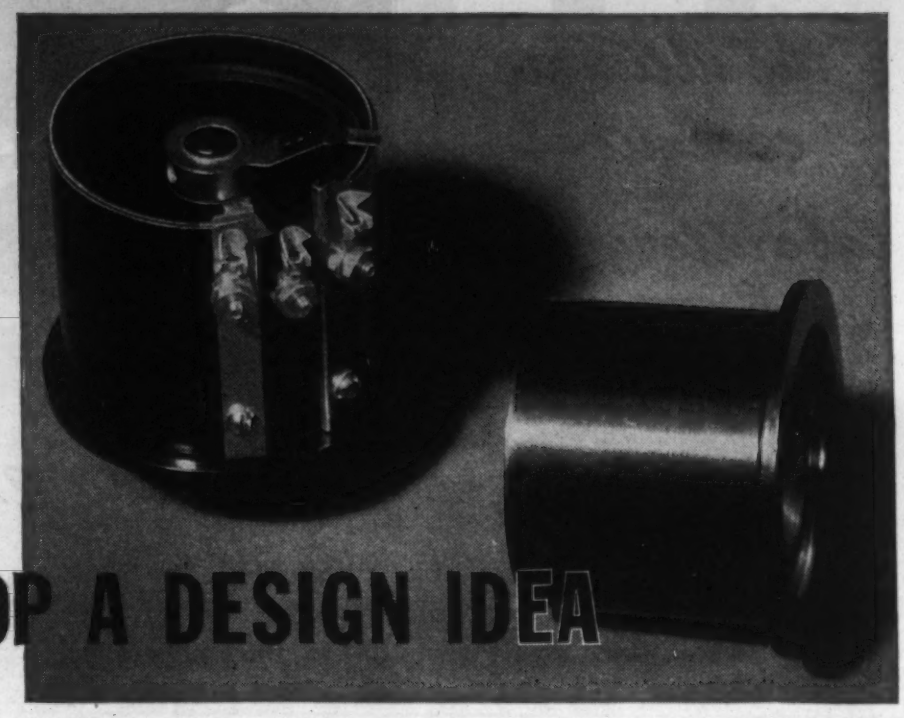
Good flexibility without undue softness is necessary for fabric coatings, but good resistance to the elements, and to other agents, such as gasoline, alcohol, acids and alkalies, is also needed.

Molding conditions necessitate good cold flow in plastics, but hardness, high impact strength, toughness and flexibility should be present in the finished material. Plasticizers can increase flow and thus insure complete filling of the cold cavity. If plasticizer content is too high, a spotted surface may result.

When plasticizer is lost, embrittlement results. For such products as insulating electric cables, protective coatings, films and sheeting, a plasticizer of low volatility is needed to prevent drying out and cracking.

The vinyls can be plasticized to give almost any degree of flexibility. The plasticizers also increase tackiness, lower temperatures required to seal thermoplastic adhesives, and lower the melting point of hot melts. Small amounts improve their ability to bend without checking, and larger proportions tend to change them from rigid to elastic rubber-like solids or soft gels.

—Leonard F. Pinto. *Plastics*, Vol. 2, Jan. 1945, pp. 24-29, 104-107.



HOW TO DEVELOP A DESIGN IDEA

More and more designers are turning to the versatility of phenolic plastics for the answer to material problems which are holding back the development of their imaginative ideas. An excellent example of this is the DeJur-Amsco Corporation of Long Island City, manufacturers of the potentiometer case illustrated above.

This case serves as a support for the surrounding resistance coil and forms the inside of the unit. A brass insert molded integrally into the base serves as a guide for the drive shaft. As you can see, the design of this potentiometer is unusually complex. Yet the custom molder was able to mold the entire job in a single operation, with the insert an integral part of the piece. This, in turn, made for simplified assembly of the finished product.

The plastic material used in this case is a Durez phenolic molding compound. The reason for the selection of this compound is readily understandable when you realize that it possesses such versatile properties as self-insulation, dielectric strength, excellent moldability, and resistance to acids, alkalies, greases, water and heat.

Perhaps you are in the process of developing a design idea and considering the use of plastics. We suggest that first you consult your custom molder whose wartime activities have advanced molding methods and processes by decades. After this preliminary discussion, we suggest that you benefit from the vast experience which Durez technicians have acquired through active participation in successful product development during the past quarter century by availing yourself of their services.

The wealth of data in our files plus the complete cooperation of the Durez staff are available towards the solution of any materials problem which you may have.

Durez Plastics & Chemicals, Inc., 272 Walck Road, North Tonawanda, N. Y.

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PHENOLIC RESINS

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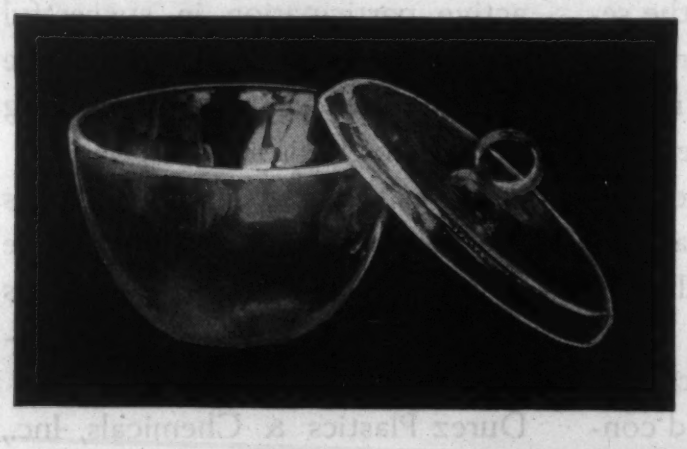
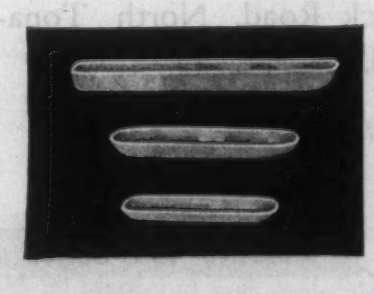
Indifferent to thermal shock, unaffected by most acids and halogens (regardless of concentration or temperature), and highly resistant to extreme electrical conditions, Vitreosil (vitreous silica) is uniquely adapted to exacting analytical and research work in metallurgy.

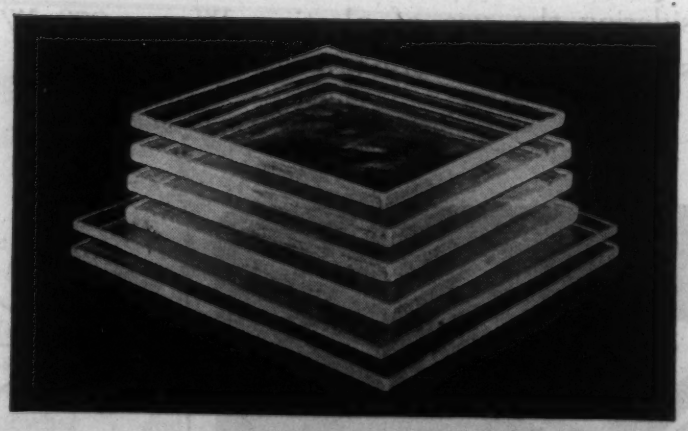
Greater chemical purity makes Vitreosil a superior replacement for porcelain, glass, and other ceramics. Low initial cost—as compared with platinum—has led to its universal adoption for laboratory applications involving high temperature ranges.

Standard items of Vitreosil laboratory ware include crucibles, combustion boats, casseroles, beakers, flasks, test tubes, evaporating dishes, muffles, trays, plates, and tubing.



Write for Bulletins Nos. 10 and 11 on standard apparatus and utensils in transparent and non-transparent ware, respectively.





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Wartime Fabric Developments

Condensed from a Paper of the Society of Automotive Engineers

Fabrics for use as automotive upholstery should have long life, good wear resistance, maximum style and beauty, ease of handling, elasticity and softness, ventilation for dissipation of heat, and maximum resistance to spotting. A variety of natural fibers, semi-synthetics, and complete synthetics are available for these fabrics.

In considering long life and wear resistance, vinylidene chloride is a first thought. The vinyl polymers, whether in sheet form or as impregnants, or coatings for yarn and fabric, also have outstanding qualities of wear resistance.

Vinyl butral is thermoplastic in its earlier stages, but can be handled on regular rubber machinery and subsequently cured to resist heat. Vinylidene chloride is still rather harsh to the touch, and would appear to serve hard-usage needs, as in trucks, rather than in the family car.

With the exception of synthetic rubbers, the new synthetics are color-receptive in the extreme. Besides having access to an unlimited spectrum, we are assured that many familiar materials will reappear in new attractive weaves.

Because scientific control of fiber, filament, or sheet is assured, and because many of the new materials can be solvent—or heat-fused, we may predict that they will, in general, be easier to handle than their predecessors.

Many of the new synthetics are elastic by nature. Vinylidene chloride is now being extruded at smaller diameters, 0.004 in. instead of 0.030 to 0.012 in., and a more comfortable weave results. New acetate rayons look well and stand up very well. Other worthy developments employ chemically-treated viscose rayons. Nylon and Fortisan in spun yarn form may be set aside for special blending in automotive use when these filaments are again run in daily consumer goods production.

Due to their physical natures, synthetic filaments are intrinsically cooler than standard natural fibers. The short-haired velvet with pile anchored in a flexible open rubber base can now be duplicated in synthetic rubbers and vinyls that are as practical and comfortable, and oil- and gasoline-resistant as well.

While no true sheet material will breathe, and enclosed seating should be air-permeable, sheet and coated materials can be made more comfortable by means of embossing, or can be perforated or cut into strips and web-woven.

A vinyl latex susceptible of water dispersion and coagulation about individual fibers offers unusual promise. We may expect water-repellent fabrics that are permeable to air and resistant to flame and abrasion as well.

Use of vinyls via the Plexon method, in which individual yarns are impregnated and coated, also permits free ventilation. Other thermoplastic resins, such as cellulose acetate and cellulose acetate butyrate, are also used in this manner. Plexon yarns have been called the most nearly tailor-made of all the fabric yarns.

The larger part of our new synthetics,

BAKELITE

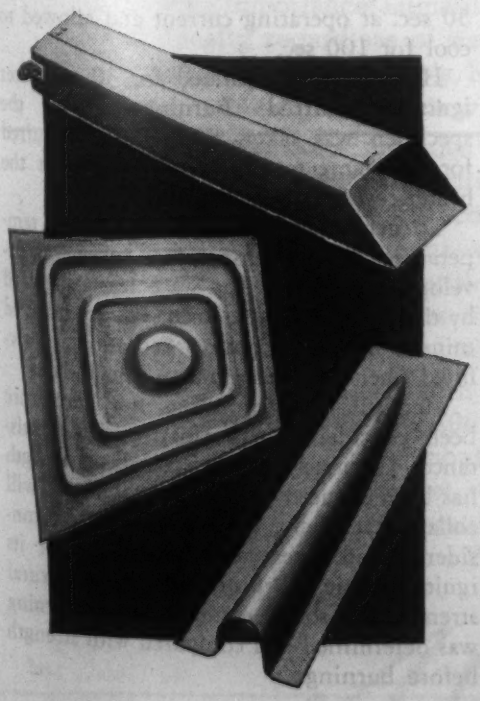
TRADE-MARK

THE EARTH WAS FLAT *ONCE!*

At least, for thousands of years people *thought* the earth was flat. Likewise, it is *now* generally thought that flat laminated sheet stock must remain flat, no matter how machined or manipulated. But science proved the earth a sphere, and recent developments have shown that flat stock can readily be "postformed" — with curves and compound curves for a wide variety of practical purposes.

The fact is, that, conventional flat laminated sheets, when impregnated with BAKELITE laminating varnishes, and heated to a sufficiently high temperature, have a very useful measure of residual thermoelasticity. A simple postforming technique has been developed for turning this characteristic to account—first, by a heat-softening process, and then by pressure-forming in a cold die. Calling only for inexpensive tools and the standard methods associated with metal working, postforming speeds up production and brings substantial die cost savings. The finished products are lightweight, structurally stable, and endowed with high mechanical strength.

The postforming of flat laminated sheets creates a wealth of opportunities for new and improved product designs. Further information about the postforming technique and its range of possibilities will be sent you gladly upon request. Write Department 49.



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DEEP DRAWING

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Bossert maintains a staff of skilled engineers and designers and has solved many problems for its customers over the past thirty years. It has served the leading concerns in such industries as the automotive, refrigerator, electric washing and drying machines, electric power equipment, oil burning furnaces, water heater, tractor, concrete mixer, garment pressing machine, radio, rayon yarn, business machine, industrial filters, domestic sinks, railway supplies, gasoline curb pumps, airplanes, fire extinguisher, dairy, automotive accessories, and many others.

Our capacity for deep drawing is 54" diameter x 18" deep, or 39" x 72" x 12", in all metals, and up to 7/16" gauge. *OVER 200,000 SQUARE FEET OF FLOOR SPACE!*

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Amersil* is unaffected by any of the mineral acids—except hydroflouric (at all temperatures), and phosphoric above 270°F.—or by the halogens, with the exception of flourine. It withstands, permanently, temperatures up to 2100° F., with peaks up to 2700°F. permissible for short periods. Amersil's ability to withstand sudden and extreme thermal shocks without noticeable expansion or contraction is another of its many valuable characteristics.

For purer finished products, use Amersil*, apparatus.

A new Amersil* Catalog is on the press. Write today—on your business letterhead, please—and reserve a copy.

*The registered trade name of the only American manufacturer of a complete line of fused silica products.

AMERSIL COMPANY Inc.

A subsidiary of Nichols Engineering & Research Corp.

60 WALL TOWER NEW YORK 5, N. Y.

whether fiber, filament, or coated sheet, are grease and dirt resistant, and are cleaned with relative ease. Even the older "found" fibers can now be impregnated or coated by several processes.

The synthetics are mothproof, and the rayons, nylon, vinylidene chloride, and the vinyls are largely unaffected by mildew, sunlight, and other destructive agents normally encountered in every-day usage.

—Morris Sanders. *Soc. Automotive Engrs.* paper, January 1945 meeting, 8 pp.

Flame Resistance of Plastics

Condensed from "ASTM Bulletin"

Since current methods of determining flame-resisting characteristics of plastics are inadequate, this investigation is concerned with developing a suitable method for determining flame-resistance of thermosetting plastics.

A flame-resistant material is one possessing the following characteristics: (1) High ignition temperature, (2) low burning time, (3) absence of smoldering after flame is extinguished, (4) retention of mechanical strength after burning, and (5) minimum distortion caused by exposure to test.

A method found to be satisfactory was developed in the Materials Laboratory, Navy Yard, New York. A nichrome coil is used as a heating element, with the specimen supported in a vertical position within the coil. Materials are rated in terms of ignition time and burning time.

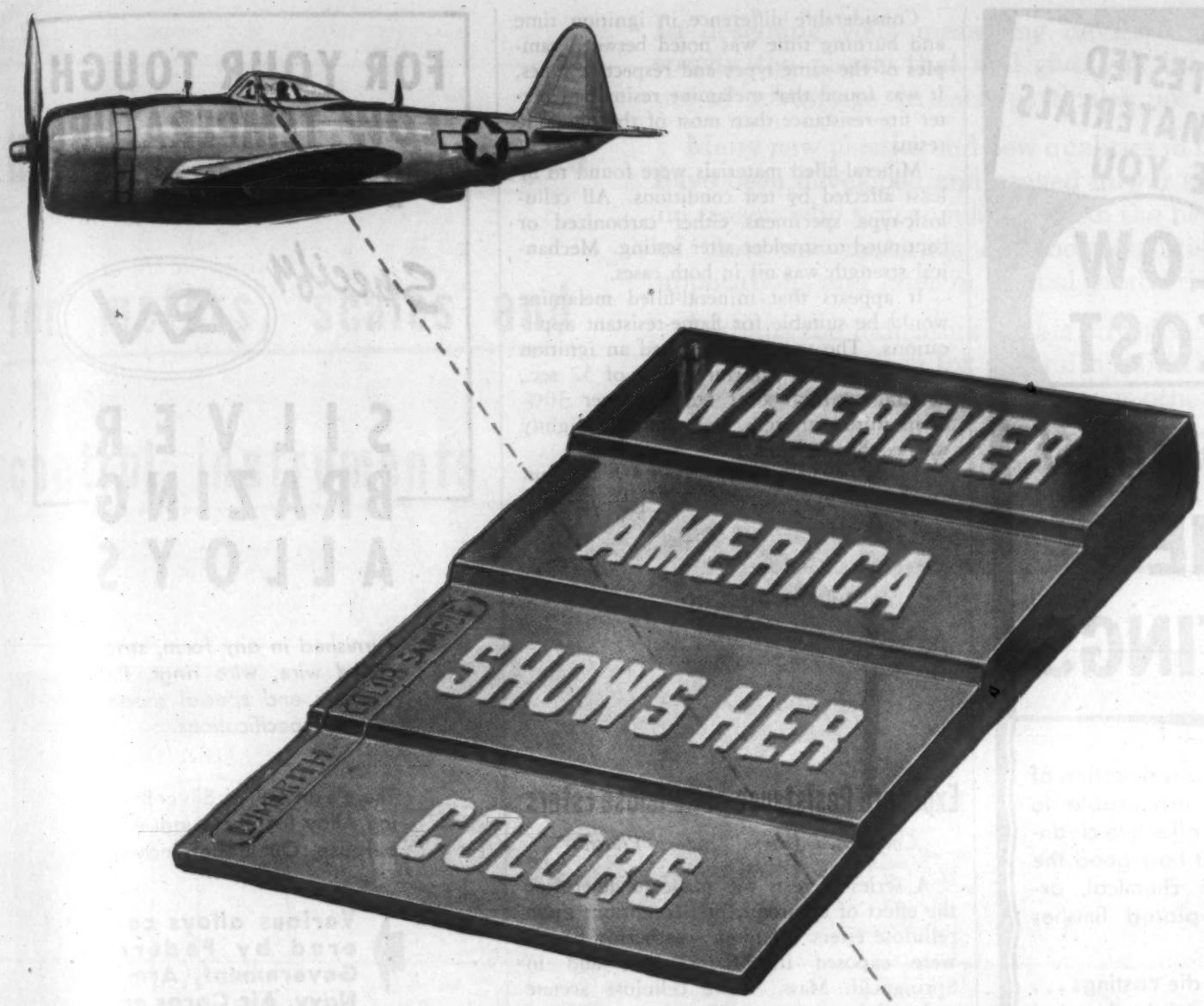
Specimens ½ x ½ x 5 in., of the type used for flexural strength tests, were used. Samples of molded material were fabricated to finished dimensions in a standard test mold, and laminated samples were cut from ½-in. sheet stock.

Tests were conducted with a current of 55 amp. passing through the heating coil. To insure similar starting conditions for all samples, the coil was preheated for 50 sec. at operating current and allowed to cool for 100 sec.

Heating was continued for 30 sec. after ignition occurred. Burning time of the specimen was taken as the time required for the flame to extinguish itself after the heater-coil was de-energized.

To determine approximate ignition temperatures, a time-temperature curve was developed. Samples that were least distorted by the flame test were used. These included mineral-filled melamine, asbestos fabric-filled phenolic, and grade AA materials.

Mechanical strength has not heretofore been considered in evaluating flame resistance. Obviously, a material whose strength has been reduced to the extent where it will collapse at slight pressure cannot be considered flame resistant, irrespective of its ignition time, burning time, etc. Flexural strength of some materials after burning was determined and compared with strength before burning.



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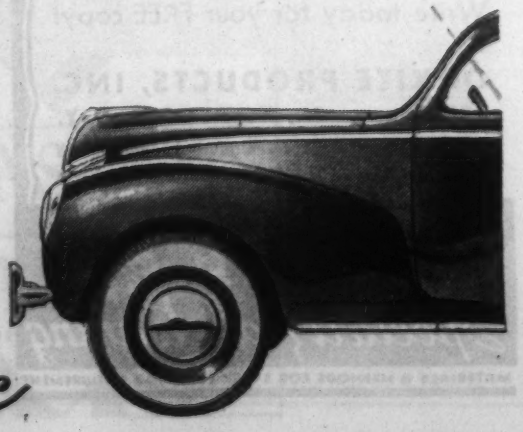
The Lumarith group brackets the thermoplastic field in toughness, tensile strength and stability. If you would like to know more about these versatile materials, write for designer's booklet. Celanese Plastics Corporation, a *division of Celanese Corporation of America*, 180 Madison Avenue, New York 16, N. Y.



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Considerable difference in ignition time and burning time was noted between samples of the same types and respective types. It was found that melamine resins had better fire-resistance than most of the phenolic resins.

Mineral-filled materials were found to be least affected by test conditions. All cellulosic-type specimens either carbonized or continued to smolder after testing. Mechanical strength was nil in both cases.

It appears that mineral-filled melamine would be suitable for flame-resistant applications. The sample tested had an ignition time of 324 sec., burning time of 52 sec., flexural strength after burning over 30% of its initial strength, and was only slightly warped by burning.

—J. A. Gale, R. W. Stewart & J. B. Alfers, *ASTM Bulletin*, No. 131, Dec. 1944, pp. 23-27.

Exposure Resistance of Cellulose Esters

Condensed from "Modern Plastics"

A series of tests was made to determine the effect of environmental conditions upon cellulose esters. Outdoor weathering panels were exposed in Miami, Fla., and in Springfield, Mass., using cellulose acetate and cellulose nitrate. The acetate material was 2050 TVA Fibestos, while the nitrate was a medium viscosity pyroxylin of about 11% nitrogen content, plasticized with 25% camphor.

Outdoor exposure caused the following results: (1) The base cellulose ester is degraded, the degree depending upon the length of exposure and intensity of incident radiation. (2) Plasticizer is lost by evaporation and by leaching. (3) Color changes due to darkening or bleaching of colorants or of basic plastic occurs, the acetates usually becoming lighter and the nitrates becoming yellower and darker.

(4) Shrinkage, and sometimes warping, usually occur upon prolonged exposure. (5) Fine surface cracks, known as crazing, and deeper cracks form after extended exposure. (6) Stresses frozen in the material during manufacture are usually released, impairing surface quality.

Cellulose acetate is moderately resistant to outdoor exposure, while cellulose nitrate tends to deteriorate rather rapidly. The acetate is more sensitive to moisture, and both are about equally resistant to moisture. Tensile strength, elongation, and yield strength decrease for both plastics with increasing exposure.

Degradation of cellulose acetate requires about three times as long as for the nitrate. Impact strength of both decreases with increasing exposure, but haze, light transmission, and shrinkage increase. Increase in light transmission is thought to be due to bleaching.

Exposure at Miami was more severe in its effects than at Springfield.

—T. S. Lawton, Jr. & H. K. Nason, *Modern Plastics*, Vol. 22, Jan. 1945, pp. 145-150, 176.

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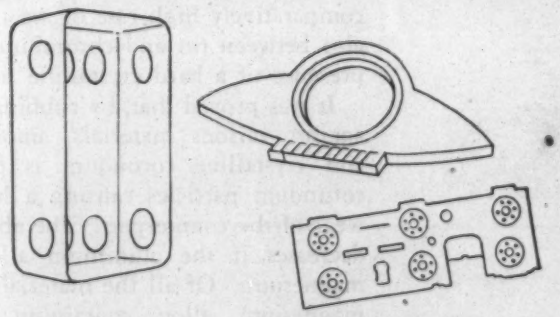
How to specify plastics for meters, scales and control instruments

In designing your measuring devices, you'll want to specify the plastic that will give you the fullest measure of advantage, in each particular use.

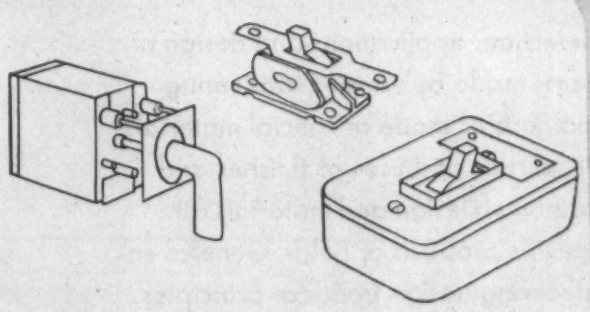
Many new plastics and new qualities in former plastics have been developed and proved in war service. There's no reason why you shouldn't make the best possible use of these new materials and new qualities now in war applications and later in normal production.

Perhaps the indicators in this advertisement will help in making selections for general applications. For complete information on any of these, or other plastics, contact the plastics consultants of Monsanto, producer of the widest variety of plastics in the industry, and the source of unbiased and experienced counsel on which kind of plastic to use in which spot. Write, wire or phone: MONSANTO CHEMICAL COMPANY, Plastics Division, Springfield 2, Massachusetts.



HOUSINGS, PANELS, BEZYLS

Molded Resinox, Fibestos, Lustron, Cerex, Resimene, or Thalid impression moldings.



CONTROLS, KNOBS, INDICATORS

Molded Lustron, Nitron, Resinox, Fibestos

DIALS, CRYSTALS, ETC.

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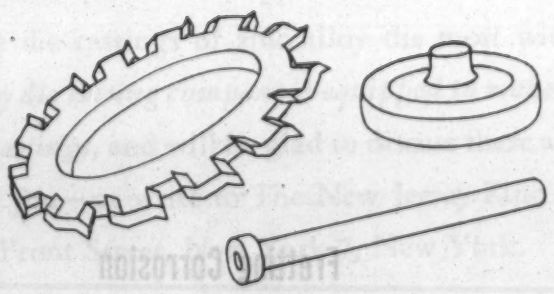
Molded Scales — Lustron
Crystals—Molded Lustron, Fibestos Sheets



FUNCTIONAL PARTS

Insulating Parts—Styramic HT, Resinox, Cerex
Mechanical Parts—Molded Resinox, Resimene; Laminated Resinox, Resimene

The broad and versatile Family of Monsanto Plastics includes: Lustron polystyrenes • Cerex heat resistant thermoplastics Vinyl acetals • Nitron cellulose nitrates • Fibestos cellulose acetates • Resinox phenolics • Thalid for Impression Molding Resimene melamines. Forms in which they are supplied include: Sheets • Rods • Tubes • Molding Compounds • Industrial Resins • Coating Compounds • Vuepak rigid, transparent packaging materials.

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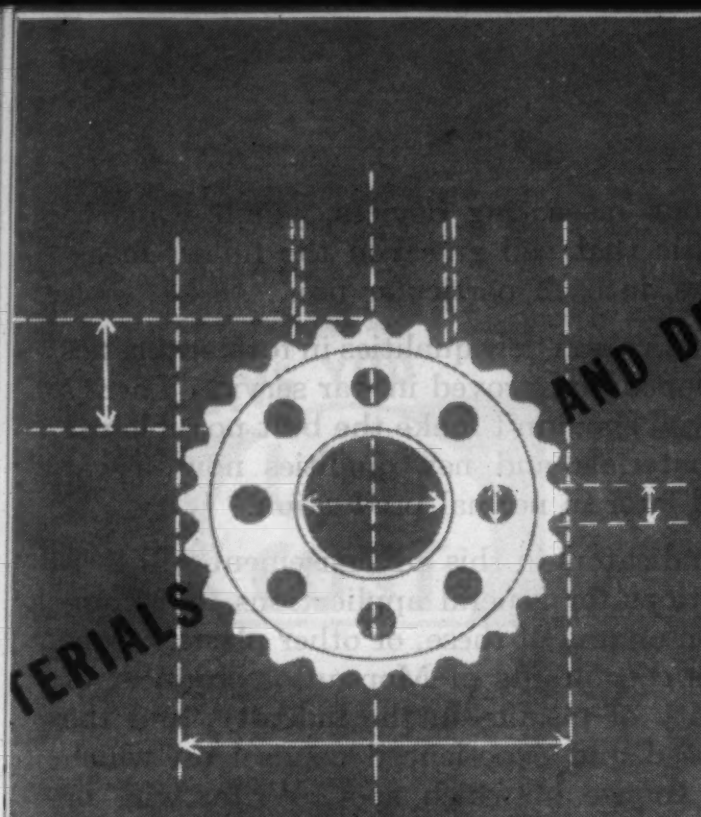


GENERAL PRODUCT DESIGN

Selection, applications and design of parts made by various fabricating methods or made of special materials. Properties and uses of finishes and coatings. Design and materials for specific products or fields. General engineering design trends or principles.

Fretting Corrosion

Condensed from "Engineers' Digest"

Fretting corrosion defines a series of wear phenomena occurring between two surfaces, of which one at least must be metallic, in the presence of oxygen, usually only slight sliding motion taking place between the surfaces.

In order to produce fretting oxides for chemical analyses and to examine their resistance to friction, test specimens were prepared of various types of steel, tin, zinc, copper, light alloys, and a plastic material. For the counterpart, hardened chromium steel, nitrided steel, aluminum and cemented carbide steel were used.

Weight measurements before and after the test estimated the amount of wear occurring. Wear debris was collected in a container protected against contamination.

Fretting oxides were formed over a very short period. After the first few to and fro motions, "smearing" could be observed on the hard counterpart, only with a soft specimen. This ceased quickly and was followed by intense oxidation. A considerable quantity of oxygen was found to be contained in the wear debris.

Debris from friction between steel and aluminum contains varying quantities of corundum, differing from ordinary corundum in that a large part of the aluminum oxide is soluble in acid. Varying amounts of nitrogen, such as nitrides of iron, chromium or aluminum, were found.

The experiments proved that the rate of wear does not increase with the hardness of the test specimen. A comparatively soft austenitic chromium nickel steel or aluminum attacked hardened steel to a greater extent than nitrided steel. The condition of wear therefore depends not only on the hardness of the material but upon the nature of the fretting oxides produced.

If the oxides stick to the surface, they can act as protection against further wear. Wear products obtained with stainless steel rubbing against chromium steel show a strong abrasive property due, it is assumed, to the presence of chromium nitrides and perhaps also chromium-nickel particles. A comparatively high rate of wear takes place also between tin and chromium due to the presence of a hard crystalline tin oxide.

It was proved that, by rubbing aluminum against various materials, amorphous clay and crystalline corundum is formed, the corundum particles causing a high rate of wear of the counterpart. The abrasive effect decreases if the aluminum alloy contains magnesium. Of all the materials examined, magnesium alloy containing 90% Mg showed the lowest rate of wear.

The hard crystalline magnesium oxide is found only in small quantity, if at all, and the bulk of the oxides consists of amorphous magnesium oxide or soft magnesium hydrate. The latter is indicated by the high hydrogen content of the debris. The highest rate of wear of the counterpart occurred with a plastic, T 3.

In the presence of a lubricant between the two surfaces, fretting corrosion can only occur with boundary lubrication, provided that oxygen has access to the surfaces. With paraffin oil or bearing oil no appreciable amount of wear took place with aluminum or plastic material rubbing against chromium steel.

Fretting corrosion can cause fatigue failure as well as destruction of surfaces. No definite fatigue strength figure can be quoted for clamped parts because of the change in cross-section caused by the high rate of wear due to fretting corrosion.

—Kurt Dies. *Z. des V.D.I.*, Vol. 87, July 1943, pp. 475-476; as abstracted in *Engineers' Digest*, British, Vol. 5, Nov. 1944, p. 324.

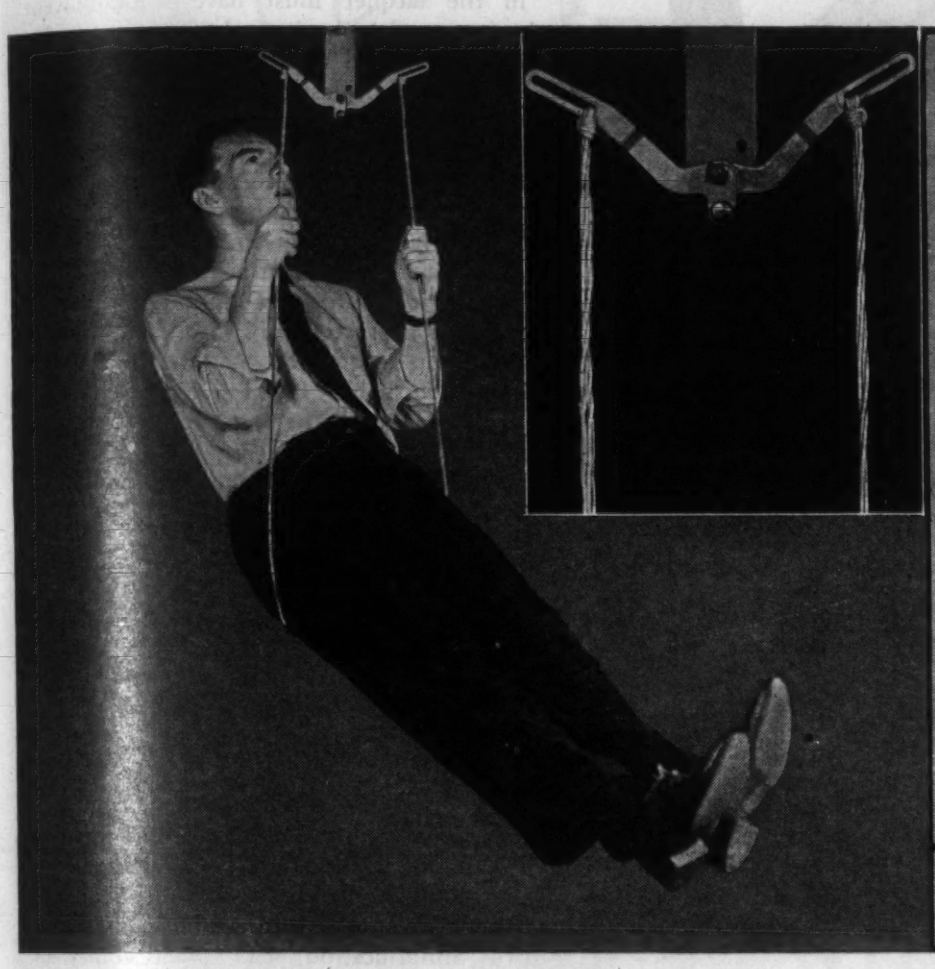
Painting Plastics

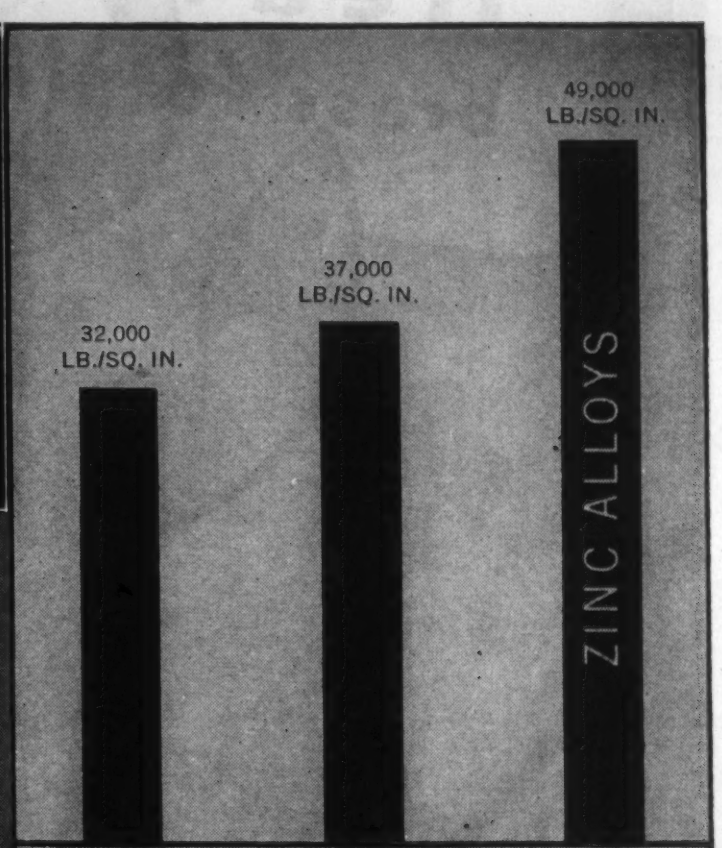
Condensed from "Industrial Finishing"

The natural finish on most sheet, tubular and molded plastics is usually the most attractive. However, it is sometimes desirable to enhance the natural finish, or a special

TENSILE!

—ZINC ALLOY DIE CASTINGS CAN TAKE A "MAN-SIZED" LOAD





AVERAGE TENSILE STRENGTH VALUES
(FROM DIE CAST TEST SPECIMENS)
for the commonly used Die Casting Alloys

This simple test of a pair of zinc alloy die cast brackets (see close-up) was made to dramatize tensile strength. There was no need for the gentleman's tense expression—the zinc alloy die cast brackets easily sustained his weight without deformation. You may never have a part with equivalent demands for tensile strength, but this test graphically illustrates the physical characteristics of zinc alloy die castings.

Tensile strength is just one of the physical properties of the zinc die casting alloys which is not equaled by either of the other commonly used die casting metals. Zinc alloy die castings are also superior in impact and compressive strength, ductility and hardness.

These strength characteristics, coupled with speed of production, clean-cut appearance and low cost, have made die castings of zinc alloy the most widely used. *Every die casting company is equipped to make zinc alloy die castings,* and will be glad to discuss these advantages with you—or write to The New Jersey Zinc Company, 160 Front Street, New York 7, New York.

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The Research was done, the Alloys were developed, and most Die Castings are specified with
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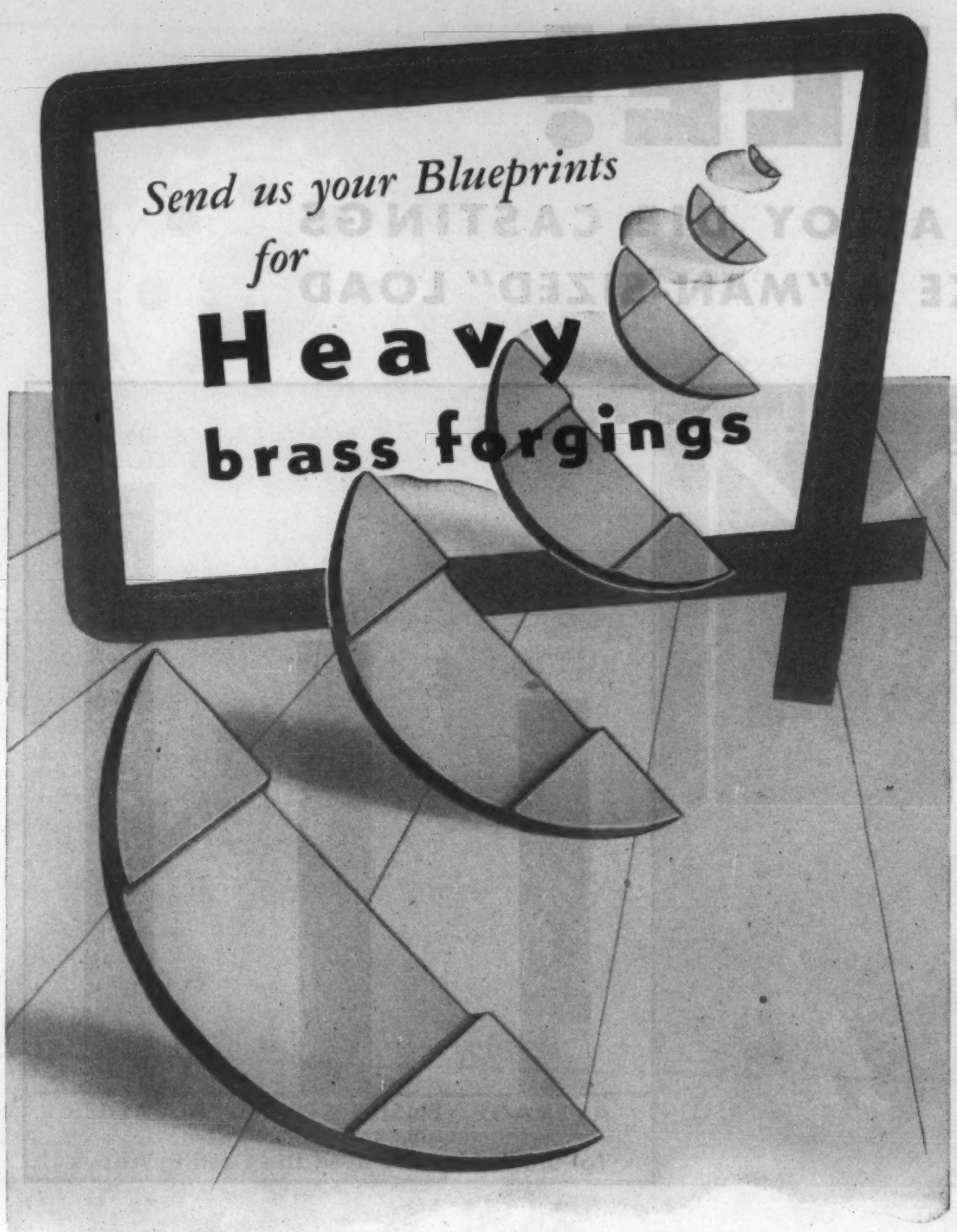

★ TITAN METAL MANUFACTURING COMPANY now has some open capacity for heavy Brass Forgings (up to 100 pounds.)

Owing to the unusual demands for war materials, we have stepped up our forging capacity and are now manufacturing brass forgings, ranging from 1/4 oz. to 100 lbs. The accompanying illustrations show a 1/4 oz. TITAN brass forging and a 26 lb. TITAN brass forging.

Note: The only open capacity we have is for very heavy brass forgings.

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finish may be required on a low cost plastic that may have a poor natural finish.

Metal, dye and paint finishes are considered. Plastics can be plated satisfactorily with any of the well-known metals, *e.g.*, copper, brass, nickel, chromium or silver.

A dye suitable for plastics has also been developed. The plastic is immersed in a hot-water solution of the dye for two min. The dye penetrates to a considerable depth without harming the surface.

A spray lacquer can also be applied. In order to have good adhesion, the solvents in the lacquer must have some solvent action on the plastic, and yet must not distort its surface. Since a number of different kinds of plastic are now available, a lacquer that will give good results on one kind may not be satisfactory on another. A suitable lacquer formula for a given plastic must be determined in the laboratory or by trial and error in the user's factory.

An example is described in which a railroad light fixture, part aluminum and part plastic, was successfully lacquered with an aluminum lacquer so that the plastic was indistinguishable from the metallic aluminum parts. The lacquer, which was thinned with acetone, was applied by spraying. The adhesion of the lacquer film to the plastic was excellent.

—A. L. Medel. *Ind. Finishing*, Vol. 21, Dec. 1944, pp. 56, 58.

Production Considerations in Design

Condensed from "Product Engineering"

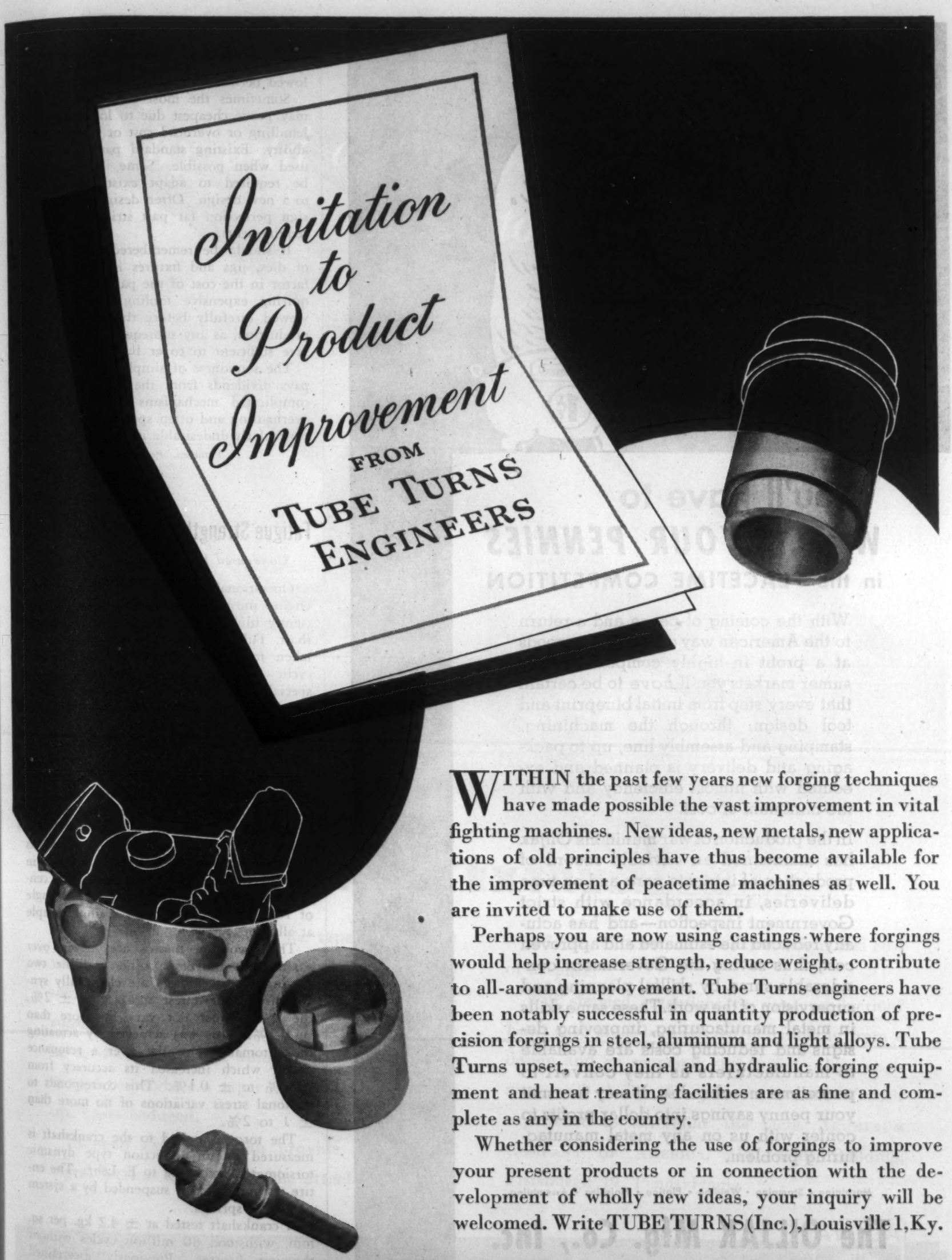
The aim of the production design engineer is to modify and simplify a proposed product to facilitate its manufacture without sacrificing strength or functional efficiency. This involves the following factors: (1) Simplification, (2) practicability of assemblies and installations, (3) elimination of close limits and clearances, (4) use of existing parts and standards, (5) use of readily available materials, and (6) serviceability.

The fewer the parts necessary, the less the stock handling, the fewer the records and space required, and the greater the production.

Subassemblies permit the use of small, simple jigs and avoid congestion. The tooling must permit interchangeability between identical subassemblies, and should be adequate to last for the contract involved without excessive maintenance. Close cooperation between all departments is necessary to choose the best breakdown for subassemblies, since the greater their number, the greater the number of fastening operations.

Bench assemblies of complete units that can be installed with a minimum of clamping or bolting should be used if possible. It is important to watch the line flow of materials and the stationing of the assembly operations.

Tolerances should be as great as operation of the product will permit. Where interchangeability requirements are rigid, the design must permit full coordination of the attaching and mating points. Close tolerances are ineffective if irregularities of the surrounding structure are not taken



WITHIN the past few years new forging techniques have made possible the vast improvement in vital fighting machines. New ideas, new metals, new applications of old principles have thus become available for the improvement of peacetime machines as well. You are invited to make use of them.

Perhaps you are now using castings where forgings would help increase strength, reduce weight, contribute to all-around improvement. Tube Turns engineers have been notably successful in quantity production of precision forgings in steel, aluminum and light alloys. Tube Turns upset, mechanical and hydraulic forging equipment and heat treating facilities are as fine and complete as any in the country.

Whether considering the use of forgings to improve your present products or in connection with the development of wholly new ideas, your inquiry will be welcomed. Write TUBE TURNS (Inc.), Louisville 1, Ky.

TUBE TURNS *Forgings for Industry*

You'll have to *WATCH YOUR PENNIES* in the PEACETIME COMPETITION

With the coming of peace and a return to the American way of producing goods at a profit in highly competitive consumer markets you'll *have* to be certain that every step from initial blueprint and tool design, through the machining, stamping and assembly line, up to packaging and delivery is planned and executed with utmost efficiency and with the minimum of cost.

In the production of war munitions Oiljak has maintained an enviable record of production of intricate parts and on time deliveries, in accordance with strict Government inspection—and has actually reduced the estimated and approved cost, thus saving the Government considerable sums, by skillful planning and supervision of the work. These same skills in metal manufacturing, improving designs and reducing costs are available to manufacturers as they convert to peacetime merchandise. It may transmit your penny savings into dollar profits to confer with us on any metal manufacturing problem.

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THE JOB COMPLETE . . .
from blueprint to finished product

into consideration. Loose fit drill holes should be used when a closer fit is not required. Adequate clearance should be allowed between moving and fixed parts.

Sometimes the most expensive material may prove cheapest due to lower labor or handling or overhead cost or greater availability. Existing standard parts should be used when possible. Some ingenuity may be required to adapt existing standards to a new design. Often designers carry design perfection far past strictly functional requirements.

It should be remembered that the cost of dies, jigs and fixtures is an important factor in the cost of the parts. Designs requiring expensive tooling should be reviewed carefully before they are put into production, as any subsequent change must save sufficient to cover both sets of tools.

The soundness of simplified designs also pays dividends from the service angle as complicated mechanisms require frequent overhauling and often special tools that are particularly undesirable in field repair work.

—A. H. Petersen. *Prod. Engineering*, Vol. 15, Dec. 1944, pp. 813-817.

Fatigue Strength of Diesel Crankshafts

Condensed from "Engineers' Digest"

Operational reliability of a large Diesel engine must largely depend upon a sufficiently high fatigue strength of the crankshaft. Full size tests have now been undertaken for the first time to ascertain the cyclic torsional fatigue strength, paying special attention to the influence of flaws of the kind revealed by the Magnaflux method.

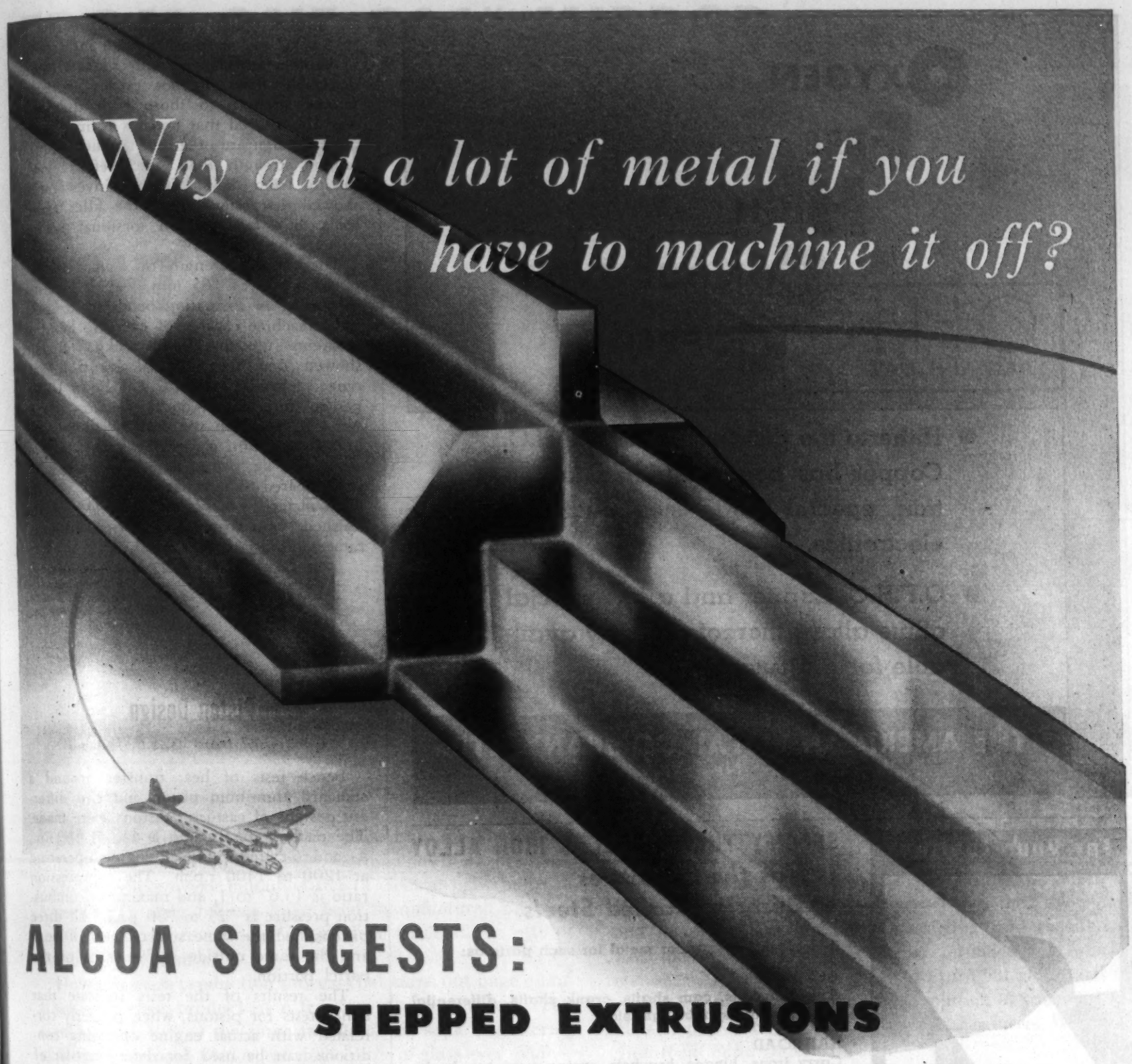
Tests were conducted on sections of crankshafts with a 245-mm. crankpin diam. made of steel St. C 35.61. The oscillating system employed to generate the cyclic torsional stresses consists of two pairs of iron bars, one pair each being clamped over webs. The system is operated below its natural frequency, both masses revolving in equidirectional synchronism with their centers of gravity, always enclosing an angle of 180 deg. This produces a single couple at all times.

The revolving masses are driven over shafts with universal joints and the two driving electric motors are electrically synchronised. For a test accuracy of $\pm$ 2%, the speed must not vary by more than $\pm$ 0.2%. This was achieved by actuating the automatic controller over a resonance circuit which increased its accuracy from $\pm$ 1% to $\pm$ 0.1%. This corresponds to torsional stress variations of no more than $\pm$ 1 to 2%.

The torque applied to the crankshaft is measured by an induction type dynamic torsiometer, according to E. Lehr. The entire testing device is suspended by a system of helical springs.

A crankshaft tested at $\pm$ 4.2 kg. per sq. mm. withstood 80 million cycles without showing fissures. Previously ascertained flaws did not undergo any changes. With the stress increased to $\pm$ 5 kg. per sq. mm., a fissure originating in the cylindrical part of the crankpin appeared at approximately

(Continued on page 784)



ALCOA SUGGESTS:

STEPPED EXTRUSIONS

Airplane wing spar caps call for tapers consistent with strength requirements. Reducing straight sections to a taper requires expensive, time-consuming machining. Alcoa's stepped extrusions can be used to reduce the amount of metal to be removed to produce a taper. Production is speeded up, costs reduced.

Stepped extrusions can provide a larger, integral section from which the attachment fitting is cut out. This avoids the extra weight and cost of a splice.

Will stepped extrusions fit your production? Each case must be analyzed individually from a design and an economic standpoint. Alcoa engineers will gladly give you the benefit of their experience to determine the facts. ALUMINUM COMPANY OF AMERICA, 2162 Gulf Building, Pittsburgh 19, Pennsylvania.

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Z-Metal is the superior metal for such parts as:

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Axle housings, cam shafts, crank shafts, differential housings, truck housings, etc.

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Carry irons, hinges, brackets, spring retainers, brake shoes and heads.

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TOOLS
Wrenches and wrench handles, hammer heads, clamps, shears, snips, etc.

In fact, wherever maximum strength coupled with minimum weight and high machinability is desired, Z-Metal should be investigated. In writing for further information, tell us about your product.

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25 million cycles. Increasing the stress to ± 5.6 kg. per sq. mm. brought failure.

Another test showed that cranks without detectable flaws do not possess superior fatigue strength to those with them. It was also proved that notches forming part of the design are of greater influence upon fatigue strength than notch effects originating from flaws. Further investigation showed that reduction in the fillet radius leads to a reduction in torsional fatigue strength by some 10%.

The fatigue strength of cranks with a pin diameter of 165 mm. was determined by testing in a rotating bending stress fatigue machine capable of exerting bending moments up to 20,000 mkg. Results showed that the nominal limiting safe range of bending stress lies at 12 to 13 kg. per sq. mm., based on the section of the web. If based on the cross sectional area of the crankpin, a limiting safe range of stress of 4 kg. per sq. mm. is obtained.

Compared to tests on round bars of the same material, the fatigue strength of the finished crankshaft must be considered rather unsatisfactory.

—E. Lehr & F. Ruef. *MTZ Motortechnische Z.*, Vol. 5, Dec. 1943, pp. 349-357; as abstracted in *Engineers' Digest*, American, Vol. 1, Nov. 1944, pp. 659-662.

Piston Design

Condensed from "S.A.E. Journal"

Bench tests of heat transfer around a standard aluminum piston and two different designs of cast-iron pistons were made. The pistons are used in a 4¾ x 6½ in., 4- and 6-cylinder Diesel engine operating at 1200 to 1400 r.p.m. The compression ratio is 13.67 to 1, and maximum combustion pressure is 725 to 780 p.s.i. All three pistons had the same surface area of head and the same outside surface area of the barrel portion.

The results of the tests indicate that bench tests for pistons, when properly correlated with actual engine operating conditions, can be used for determination of heat flow and temperatures of pistons, and will be useful in design of pistons.

Definite control of the heat flow to the rings is necessary in Diesel-engine iron pistons and can best be obtained by limiting the area of the cross-section immediately above the top ring or back of all the rings.

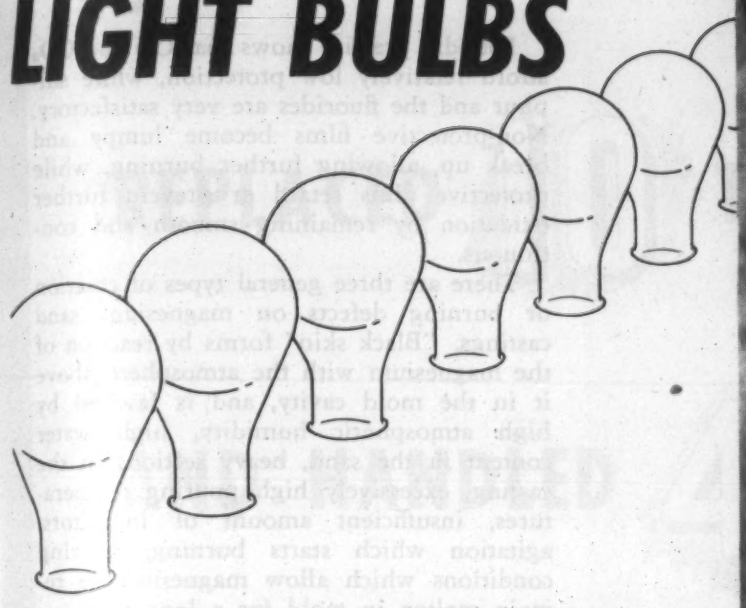
The piston rings are only 65% as effective as the ring lands and skirt of the piston for transferring heat from the piston to the cylinder wall. The larger the ring clearance, the less effective the rings become.

The thermal break between the piston surface and cylinder wall has the lowest coefficient of heat transfer of any point in the path of heat flow from the piston-head surface to the cooling water, and constitutes the major restriction to heat flow through the piston.

The proper use of ribs in the piston head definitely improves the conductivity of the piston and promotes uniform distribution of heat in the cast-iron piston with a minimum of material.

—Harry F. Bryan. *S.A.E. Journal*, Vol. 53, Jan. 1945, Trans. pp. 25-30.

FROM ONE 200" MIRROR TO BILLIONS OF LIGHT BULBS



Corning physicist examining ribbed structure of 200" mirror with polariscope.

SINCE the time it produced the glass bulb for Thomas A. Edison's first electric light in 1879, Corning has been supplying bulbs to nearly every manufacturer of electric light bulbs in America. To date billions have been manufactured on high speed automatic machines that produce them at the rate of hundreds per minute.

Here is a mass production process that turns out huge quantities of a glass product at a fraction of a cent apiece. Yet, significantly, it was the same facilities, the same engineering skill that produced the largest single piece of glass ever made—the 200" Mt. Palomar Telescope Mirror.

Only Corning has these facilities that can produce a single piece of glassware for a very special application and where cost is no consideration . . . or a million pieces made on Corning designed high speed machinery at quantity production prices. In developing new products and in redesigning you can be sure of finding at Corning the glass knowledge, the "know-how," and manufacturing facilities for meeting your requirements with glass. With thousands of glass formulae from which to choose, with the engineering skill to turn out glass parts economically, Corning may provide a solution to your problems. It will pay you to consult Corning Engineers. Write now. *Industrial Sales Dept. MA-3.*

CORNING GLASS WORKS
CORNING, NEW YORK

CORNING means Research in Glass

INDUSTRIAL GLASS by CORNING

INDUSTRIAL SALES DEPT., MA-3—
Corning Glass Works, Corning, New York

Please send me a copy of your Bulletin 842—
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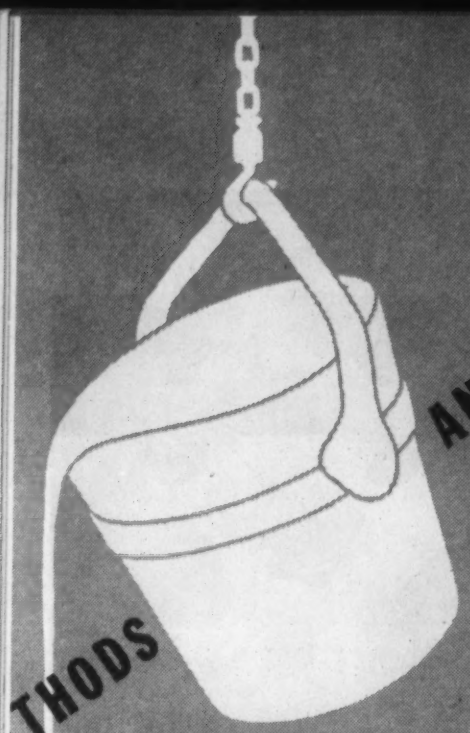


...THODS AND PROCESSES

MELTING and CASTING

Melting, alloying, refining and casting methods, furnaces and machines. Iron and steel making, nonferrous metal production, foundry practice and equipment. Die casting, permanent mold casting, precision casting, etc. Refractories, control equipment and accessories for melting furnaces.

Inhibitors for Magnesium Casting

Condensed from "The Foundry"

Molten magnesium is reactive and steps must be taken to prevent a reaction between magnesium in the mold cavity and its environment. Although the compounds added to the molding sand are termed sand inhibitors, this is a misnomer because direct reactions between molten magnesium and sand are rare. The principal function of inhibitors is to prevent reaction of magnesium with the moisture in the sand and, to a lesser extent, with the air present in the mold cavity.

In order to be effective, the inhibitor must have a protective coefficient greater than unity in the table below. The protective cofficient is the ratio of specific volume of reaction product to the specific volume of the metal.

Calculated Protective Coefficients of Inhibiting Agents

		Prot. Coeff.
(3)	$Mg+O=MgO$	0.71
(5)	$Mg+CO_2=MgO+CO$	0.71
(4)	$3Mg+N_2=Mg_3N_2$	0.79
(6)	$2Mg+CO_2=2MgO+C$	0.90
(7)	$3Mg+SO_2=MgS+2MgO$	0.92
(8)	$Mg+CO=MgO+C$	1.08
(9)	$Mg+S=MgS$	1.26
(10)	$3Mg+2BF_3=3MgF_2+2B$	1.32
(11)	$Mg+2HF=MgF_2+H_2$	1.32
(12)	$3MgO+2BF_3=B_2O_3+3MgF_2$	3.1

Foundry practice shows that CO and CO_2 afford relatively low protection, while sulphur and the fluorides are very satisfactory. Non-protective films become lumpy and break up, allowing further burning, while protective films retard or prevent further oxidation by remaining smooth and continuous.

There are three general types of reaction or burning defects on magnesium sand castings. "Black skin" forms by reaction of the magnesium with the atmosphere above it in the mold cavity, and is favored by high atmospheric humidity, high water content in the sand, heavy sections in the casting, excessively high pouring temperatures, insufficient amount of inhibitors, agitation which starts burning, pouring conditions which allow magnesium to remain molten in mold for a long time.

Black skin may be reduced by proper control of moisture and inhibitors, by flushing molds with SO_2 just before pouring, and by proper gating and skin drying of mold cavity just before pouring.

The second type of reaction defect is localized burning, which results in small gray or white pits on the surface. This is usually caused by insufficient inhibitor or too high a moisture content.

The third type is the white powdery or brown surface. This is also caused by moisture. The first type of defect occurs at a metal-air interface while the latter two occur at metal-sand interfaces. Flushing the mold cavity with SO_2 on humid days will help control the first defect, while proper conditioning of the sand will control the latter two.

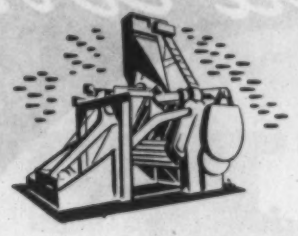
Of a large number of materials tested as inhibiting agents, only four have been found satisfactory. These are fluorides, sulphur, boric acid, and diethylene glycol. The last of these is not an inhibitor, but helps reduce moisture in the sand and probably acts as a supplementary inhibitor.

The amount of inhibitor required depends on the fineness and moisture content of the sand and on the size of the casting. Open sands with an AFA permeability of 160 would require 4.5% inhibitors, while a fine natural sand with an AFA permeability of 40 would require 10% inhibitors for the same casting.

The two types of molding sand in general use differ mainly in the presence of fluorides in one and not in the other. The absence of fluorides from the sand necessitates the use of more sulphur which, some claim, causes "sulphur blowoffs." Extensive tests show that sulphur-boric acid-diethylene glycol sands are preferable.

—L. W. Eastwood. *Foundry*, Vol. 72, Dec. 1944, pp. 82-83, 232-234; Vol. 73, Jan. 1945, pp. 80-81, 208, 210, 212.

1 WHEELABRATOR



REPLACED 10 TUMBLERS

AND HANDLED 40% MORE TONNAGE

How efficiently the Wheelabrator does its job is well expressed in the words of this typical user—a medium size Midwest foundry:

"Our action in installing a Wheelabrator three years ago was one of the best things that we have ever done in our plant as far as production betterment has been concerned. This machine has more than lived up to your claims for it, and has materially cut down our cost of operation.

"We replaced ten large mills which were taking the full time of three men—whereas the Wheelabrator takes but one man who easily keeps up to capacity. Then, too, we put through a larger tonnage by about 40% than we have ever put through our mill room before—and did it easily, which we know could not have possibly been done working overtime with tumbling mills.

"The Wheelabrator does a fine job and still leaves us with some excess capacity in our cleaning department. We are particularly well pleased with the nice finish we get on castings. They look as if they were aluminum instead of gray iron.

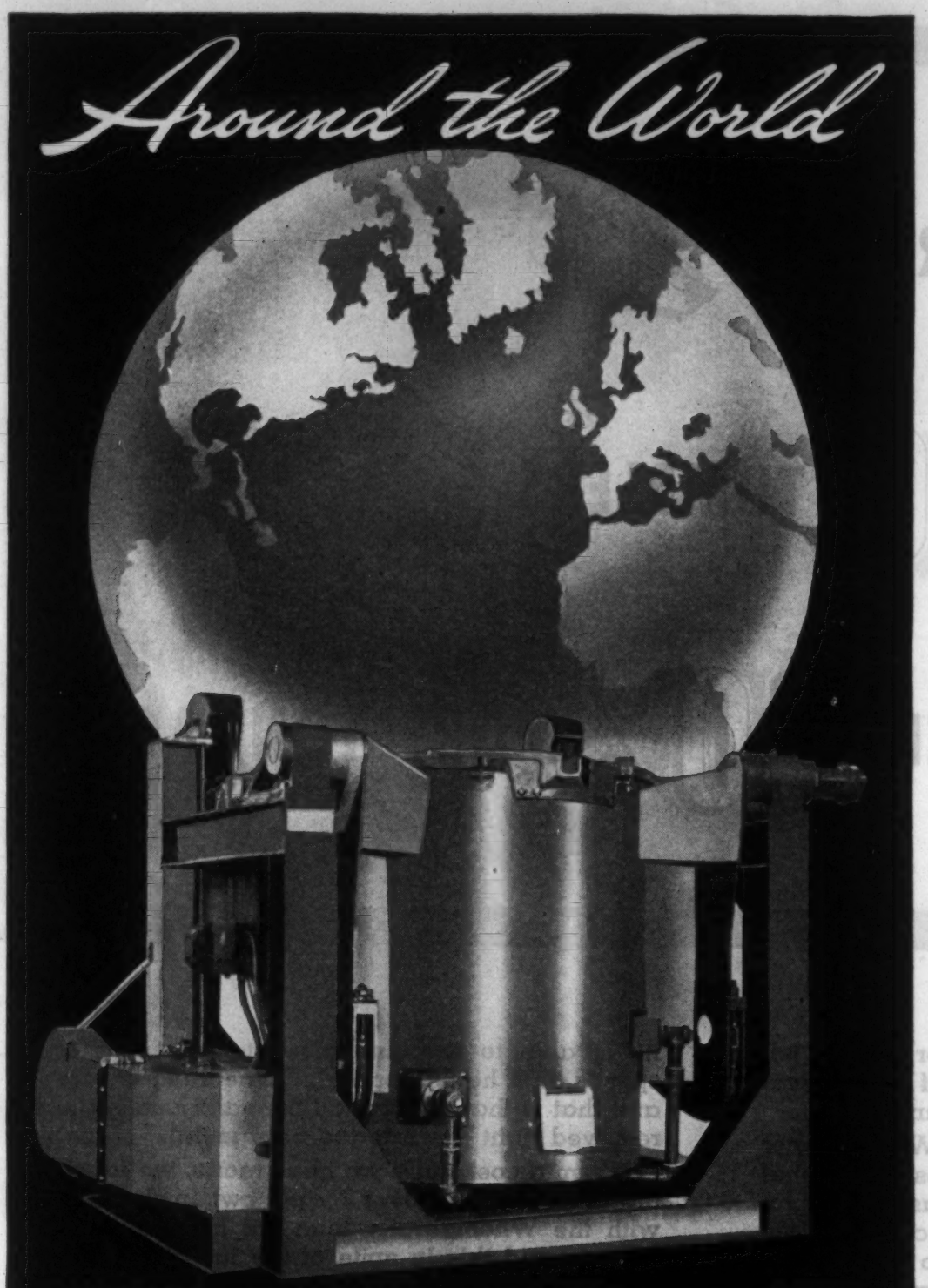
"We haven't figures to show what savings in the machine shop cost are, but the machine shop foreman tells me that his tool wear and breakage have been materially cut down and he is able to machine most items at higher speeds than he did formerly. One thing is sure and that is that you get all the sand and scale removed right down to the bare metal.

"From a cost study we have made, we found that we are saving over 2% per cwt. in cleaning with the Wheelabrator than we had over the milling, and this in spite of the fact that there had been a wage increase over the previous year of 10%."

If your cleaning operation is not functioning as smoothly as it should, or if your plans for the future require current study, be sure to investigate the Wheelabrator. Our engineers will be glad to work with you whenever you are ready.

American
FOUNDRY EQUIPMENT CO.
538 SOUTH BYRKIT STREET MISHAWAKA, IND.

WORLD'S LARGEST BUILDERS OF AIRLESS BLAST EQUIPMENT



WHERE EFFICIENT MELTING OF NON-FERROUS METALS IS REQUIRED

HAUSFELD FURNACES ARE DOING THE JOB

FURNACES FOR
BRASS • ALUMINUM • MAGNESIUM
AND ALL OTHER
NON-FERROUS ALLOYS

The Campbell-Hausfeld Co.

200-220 MOORE ST. HARRISON, OHIO

Pressure Ferrous Castings

Condensed from "S.A.E. Journal"

Although centrifugal casting was patented in 1809, not much was done commercially until after World War I. It progressed through heavy gray iron into light gray iron and then into light steel castings. Since the beginning of the present war, there have been a number of developments and expansion in the manufacture of small steel centrifugal castings.

The true centrifugal casting is spun in a metal or refractory sand mold about its own axis with the centrifugal force forming all, or most, of the inside contour. The inside form of the final part cannot be irregular to any large degree, and the outside form must be symmetrical.

Castings made in metal molds are of the highest quality and may compete with high-strength wrought parts. Examples of this type are cylinder barrels for internal-combustion engines, gears, aeroplane landing-gear parts, and tubular sections.

The semi-centrifugal casting is also spun around its own axis, but employs a core of some nature to form inside contours. Parts not entirely symmetrical and having an irregularly shaped inside form fit into this class.

High-quality castings are made in this manner, and there is a great saving in gates and risers that would be necessary if the same parts were cast statically. Examples of this class are front-wheel spindles and ball-socket joints for four-wheel-drive vehicles, and idler hubs.

Centrifuged castings are grouped around an independent central axis, and there may be layers of castings stacked one on top of another. A wide variety of shapes may be made in this manner, but without the guarantee of soundness or high physical properties, as in the other types. An example is spring bearings for universal carriers.

Casting by exerting air pressure on the molten bath from which the mold cavity is being filled is being used more as a large-scale commercial producer of specialty castings where machining is difficult.

Investment molding has been used very successfully to make castings of extreme accuracy and freedom from defects, and requiring no machining. The molds are made of a refractory material that can be controlled accurately.

Supercharger buckets are made by this method, and work is being done on tools such as cutters, hobs, and reamers. This process has its opportunity among the difficult-to-manufacture, and thus expensive, parts.

The same compositions of steel that are used for forging can be used for centrifugal casting. This field will continue to improve and develop into a much larger source of parts. The method is economical for many parts, and produces castings of such soundness and quality that they can be used for many highly stressed parts. The method is dependable to the extent that rarely are special means of inspection necessary for production castings.

Within the limits of certain designs this field should, in the future, take its place with forgings and static castings.

—E. C. Jeter. *S.A.E. Journal*, Vol. 53, Jan. 1945, Trans. pp. 19-24.

A FEW FACTS ABOUT CORHART PRODUCTS

Corhart Electrocast Refractories are high-duty products manufactured by melting selected and controlled refractory batches in electric furnaces, and casting the molten material into molds. After careful annealing, the finished shapes are ready for shipment. Dense, high-melting refractories, they are especially designed for resistance to corrosive action.

PRODUCTS

CORHART STANDARD ELECTROCAST is a high-aluminous refractory.

CORHART ZED ELECTROCAST is Zirconia-bearing.

CORHART ELECTROPLAST is a high-temperature plastic refractory made from Standard Electrocast which has been ground and crushed. Especially designed for ramming. Furnished dry.

CORHART MORTAR is a high-quality cement for laying up Electrocast, clay brick, or any aluminous refractory.

CHARACTERISTICS OF STANDARD ELECTROCAST

POROSITY: Less than 0.5%—therefore virtually no absorption.

FUSION POINT: Cone 38 without any appreciable softening below that point.

HARDNESS: 8, Mineralogist's scale.

SPECIFIC GRAVITY: Blocks weigh approximately 183 lbs. per cu. ft.

COEFFICIENT OF EXPANSION: 0.000006 between room temperature and 900° C.

SPECIFIC HEAT: 0.25 cal. per gm. per °C. at 980° C.

THERMAL CONDUCTIVITY: 25 BTU per sq. ft. per hour for gradient of 1°F. per inch.

COMPOSITION: Standard Electrocast is of an aluminous crystalline nature.

CORROSION: Because of low porosity and inherent chemical make-up, Corhart products are highly resistant to corrosive action.

APPLICATIONS

Most heat processes present spots where a better refractory material is needed in order to provide a balanced unit and reduce the expense of repeated repairs. It is for such places of severe service that we invite inquiries regarding Corhart Products as the fortifying agents to provide the refractory "balance" desired.

The following is a partial list of applications for which Corhart Products are suggested:

ELECTROLYTIC CELLS — for production of Magnesium and other light metals.

SILICATE OF SODA FURNACES — sidewalls, bottoms, and breastwalls.

HEARTHS AND SMELTERS — for non-ferrous metals.

ALKALI AND BORAX MELTING FURNACES — fast-eroding portions.

GLASS FURNACES — the entire installation of flux walls and bottoms, breastwalls, ports, tuck-stones, forehearths, recuperators, etc.

RECUPERATORS—tile, headers, separators, etc.

ENAMEL FRIT FURNACES — flux walls and bottom.

BRASS FURNACES — metal contact lining.

ELECTRIC FURNACES — linings for rocking type, and rammed linings of Electroplast for this and other types.

BOILERS — clinker line.

STOCK SHAPES AND SPECIALS

Standard and Zed Electrocast are made in stock shapes and in many special shapes. The weight of individual pieces may run to 3500 pounds.

IF YOU NEED A BETTER REFRACTORY—

● Corhart Electrocast Refractories are high-duty products which have proved considerably more effective than conventional refractories in certain severe services. If your processes contain spots where a better refractory is needed to provide a balanced unit and to reduce frequent repairs, Corhart Electrocast Refractories may possibly be the answer. The brief outline at the left gives some of the basic facts about our products. Further information will be gladly sent you on request.

Corhart Refractories Company, *Incorporated,* Sixteenth and Lee Streets, Louisville 10, Kentucky.

"Corhart" is a trade-mark, registered U. S. Patent Office.

QUALITY ECONOMY ENDURANCE

CORHART ELECTROCAST REFRACTORIES

WORKING WITH ALUMINUM?

Investigate this unique HOLDING FURNACE for Improved Operations and Lowered Costs!

Typical layout for die casting, showing compact 20 KW Ajax-Tama-Wyatt furnace in position. Unit comes with complete control cubicle, as shown.

INDUCTION FURNACES MEAN A MODERN PLANT . . .

In addition to the holding furnace here described, small, compact, twin-coil melting furnaces are likewise available for continuous production.

Rolling mills and foundries using Ajax-Tama-Wyatt units have *consistently* developed the highest physical properties in their aluminum products . . . with decreased gas absorption, absence of all segregation, and elimination of oxide inclusions and hard spots . . .

Clean-cut temperature control, great ease and simplicity of handling are operating characteristics. Ajax induction furnaces give you a modern plant, a cooler foundry, a better product. Significantly, too, they have been known to pay for themselves within less than six months.

Write for latest TW catalogs describing both Ajax holding and melting furnaces for aluminum!

ADVANTAGES

- **Every element of uncertainty is removed from holding furnace procedure.**
- **Automatic, positive temperature control to within 5 degrees.**
- **No segregation, iron pickup, or contamination—automatic stirring.**
- **Always ready to operate—no heating up or waiting periods.**
- **Pays for itself quickly by doing away with pot or crucible replacements.**
- **Maintenance costs so low as to be virtually negligible.**
- **Low operating costs—only 12 KW for holding continuously up to 400 lb.; 8 KW when covered on week ends.**
- **Greatly improved overall foundry conditions inherent in induction melting.**

AJAX TAMA-WYATT INDUCTION MELTING FURNACE

AJAX ENGINEERING CORPORATION • BOX 1418 • TRENTON 7 • N. J.

ASSOCIATE COMPANIES

AJAX METAL COMPANY, Non-Ferrous Ingot Metals and Alloys for Foundry Use
AJAX ELECTROTHERMIC CORP., Ajax-Northrup High Frequency Induction Furnaces
AJAX ELECTRIC CO., INC., The Ajax-Hultgren Electric Salt Bath Furnace
AJAX ELECTRIC FURNACE CORP., Ajax-Wyatt Induction Furnaces for Melting

Electrochemistry of Magnesium

Condensed from a Paper of the Electrochemical Society

Impurities present in the raw materials are important considerations in a magnesium process such as Dow's, the points of particular interest being those impurities found in sea water that are not common to Michigan brine, the original source of Dow's raw material.

The chief steps are: separation of magnesium chloride from the original brines, drying of the magnesium chloride to suitable "cell feed," the electrolysis of the feed in the electrolytic cell, the collection of the metal, and the utilization of the gaseous anode products. The purpose of the current discussion is to treat problems arising in the electrolytic step of the process.

Michigan brines are unique in that they contain very little potassium chloride and practically no sulphates. In the electrolysis of magnesium chloride, one prefers the use of sodium chloride to that of potassium chloride, since the former's conductivity is greater and it has the decided advantage of yielding a bath with higher specific gravity, thereby facilitating separation of magnesium metal.

Complete chemical removal of potassium chloride (more prevalent in sea water than Michigan brine) in feed preparation is difficult and will necessitate the operation of the cell on the magnesium chloride-calcium chloride-sodium chloride-potassium chloride system instead of the more easy three salt system. The potassium salt is not particularly detrimental, but should not be allowed to accumulate to the point where it reduces the specific gravity of the electrolytic bath.

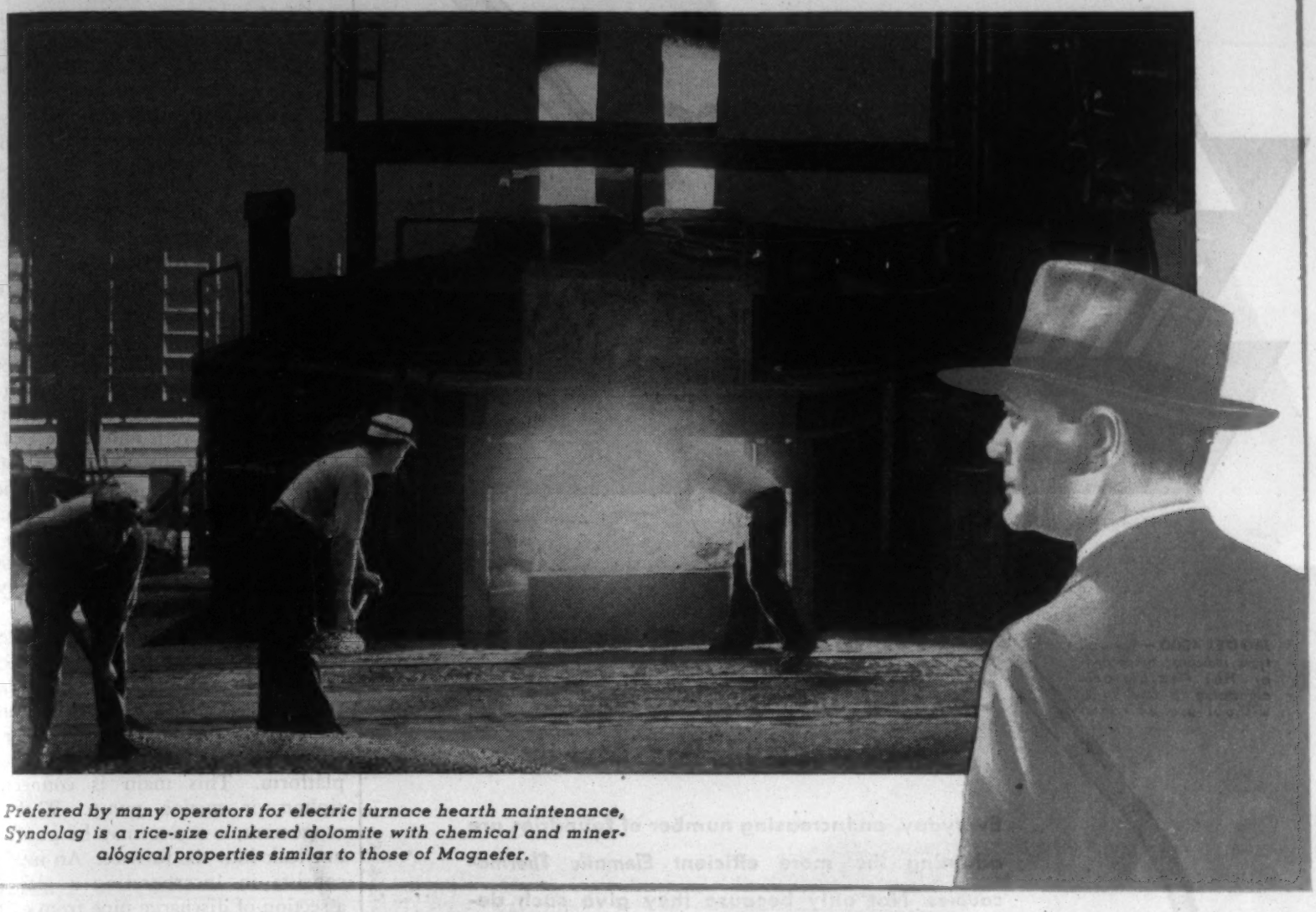
Sulphates combined with the alkali metals are detrimental. The presence of SO_4 in the raw material means that it cannot be entirely eliminated in cell feed. Fortunately, it is immediately reacted upon and does not tend to accumulate, although it does lower current efficiency, even when present to the extent of but 0.3%.

The production of magnesium from sea water is a chemical rather than an electrochemical problem, since it requires the preparation of cell feed from enormous quantities of dilute solutions. Elements found in sea water and the process operations adopted gives cell feed similar to that obtained from Michigan brines, which are really the remnants of old oceans long since evaporated. The chief impurities to be found in the cell feed are chlorides of sodium, calcium and potassium. Sulphate is present but may be kept low.

An element causing considerable trouble from sea water, not recognized at first in cell feed, is boron. It results in a mass of uncollectible metal, some sufficiently weighted down by the presence of boride to accumulate in the sludge at the bottom of the cell.

Sludge formations many times normal result, cell operation deteriorates, magnesium metal will not coalesce, and production efficiency falls. It is best controlled by chemical treatment of the weak magnesium chloride liquors.

—R. M. Hunter. *Electrochemical Soc.*, Preprint No. 86-30, Oct. 1944 meeting, 12 pp.



Preferred by many operators for electric furnace hearth maintenance, Syndolag is a rice-size clinkered dolomite with chemical and mineralogical properties similar to those of Magnefer.

"FRIEND IN NEED IS A FRIEND IN DEED"

THE thing that differentiates the Basic Refractories representative from lots of the other men who call on you is that he knows something about your industry and its refractory problems, as well as the products he's selling.

He is more than a salesman, he's a Refractories Engineer. He's a man who has actually made steel. The open hearth and the electric furnace are familiar production tools to him, because he has worked with them "on your side of the fence".

When he talks to you about basic refractories, he can give you *facts*, backed up by personal experience. What's more, you are urged to take advantage of his practical knowledge of methods of application—for building new hearths, making major repairs, or controlling heat-to-heat maintenance. It's his job to see that Basic Refractories products give excellent service in your furnace, and to help you in any other way he can.

There's many a time that a Basic Refractories man has taken off his coat and put on the overalls to help a customer in a tough spot. So think of *your* Basic Sales Engineer as your friend in need, who is a friend in deed, too.

BASIC REFRACTORIES, INCORPORATED

845 HANNA BUILDING
Cleveland 15, Ohio

MODEL 4000 — for wall type indicator or recorder. Has flexible arm adjustable to any angle without use of tools.

For Instantly and Accurately Checking the Temperature of all Nonferrous Molten Metals

Everyday, an increasing number of foundries are adopting the more efficient *Elematic Thermocouples*. Not only because they give such dependable temperature control, but because they are more economical.

All Elematic Thermocouples are equipped with our own, exclusive *Metalast Protection Tubes*— long life tubes which can be easily replaced without damaging or discarding the thermocouple, and at a saving of time and labor.

Made of a special heat resisting alloy, in types for both furnace and ladle use, Elematic Thermocouples with Metalast Protection Tubes have been tested and approved by scores of the largest brass and copper foundries in America.

DOUBLE THE LIFE OF YOUR THERMOCOUPLES WITH THIS REPLACEABLE METALAST TUBE

Simple to attach . . . fully protects thermocouple from slag or molten metal . . . drilled from solid special alloy stock without welds or seams. Available in 6″ or 8″ lengths with ½″ pipe thread.

ELEMATIC EQUIPMENT CORP.

6046 WENTWORTH AVENUE, CHICAGO 21, ILLINOIS

Blast Furnace Tuyères

Condensed from "Iron and Steel"

Of first importance in ensuring long tuyère life is the purity of the copper. Since copper is difficult to cast in the pure state, it is customary to add zinc, thus lowering the thermal conductivity of the metal. Also, mechanical unsoundness often resulted from use of iron chaplets to support the core. More recently, copper castings of high thermal conductivity are available for tuyères.

Tuyère failure may be due to the following causes: (1) Normal wear by abrasion of the nose until the thickness of metal becomes reduced and water is forced through the point of failure; (2) water stoppage in the supply sufficiently prolonged to allow water in tuyère to boil; (3) dirty water containing impurities, which silt and scale within tuyère and cause overheating; (4) poor water distribution, when bubbles of steam forming at points where iron droplets come in contact with tuyère are not removed rapidly enough to prevent superheating; and (5) iron cutting caused by molten iron dropping on tuyère and gouging through copper.

Devices most used for the detection of leakages are variants of the Foster suction system. In this arrangement, water inlet pipes are coupled through manifolds to the ring main, but the discharges are coupled to a second ring main below the tapping platform. This main is connected to a siphon or suction pump. With this arrangement, a tuyère may be punctured and not leak into the furnace. An improvement consists in incorporating a glass tube in a section of discharge pipe from each tuyère.

Tuyère piping and fittings should be arranged so as to facilitate rapid changing. Cocks should have round openings to prevent blockages, and inlet and outlet coupled by means of flexible tubing and globe union couplings.

For cleansing the tuyère system, flushing cocks should be provided at the lowest point of service manifolds. An effective way of clearing tuyères of sludge is to "kick" the tuyère by shutting off the water cock and allowing the water to boil. When the water in the discharge pipe is thrown out by steam pressure, the cock is turned on.

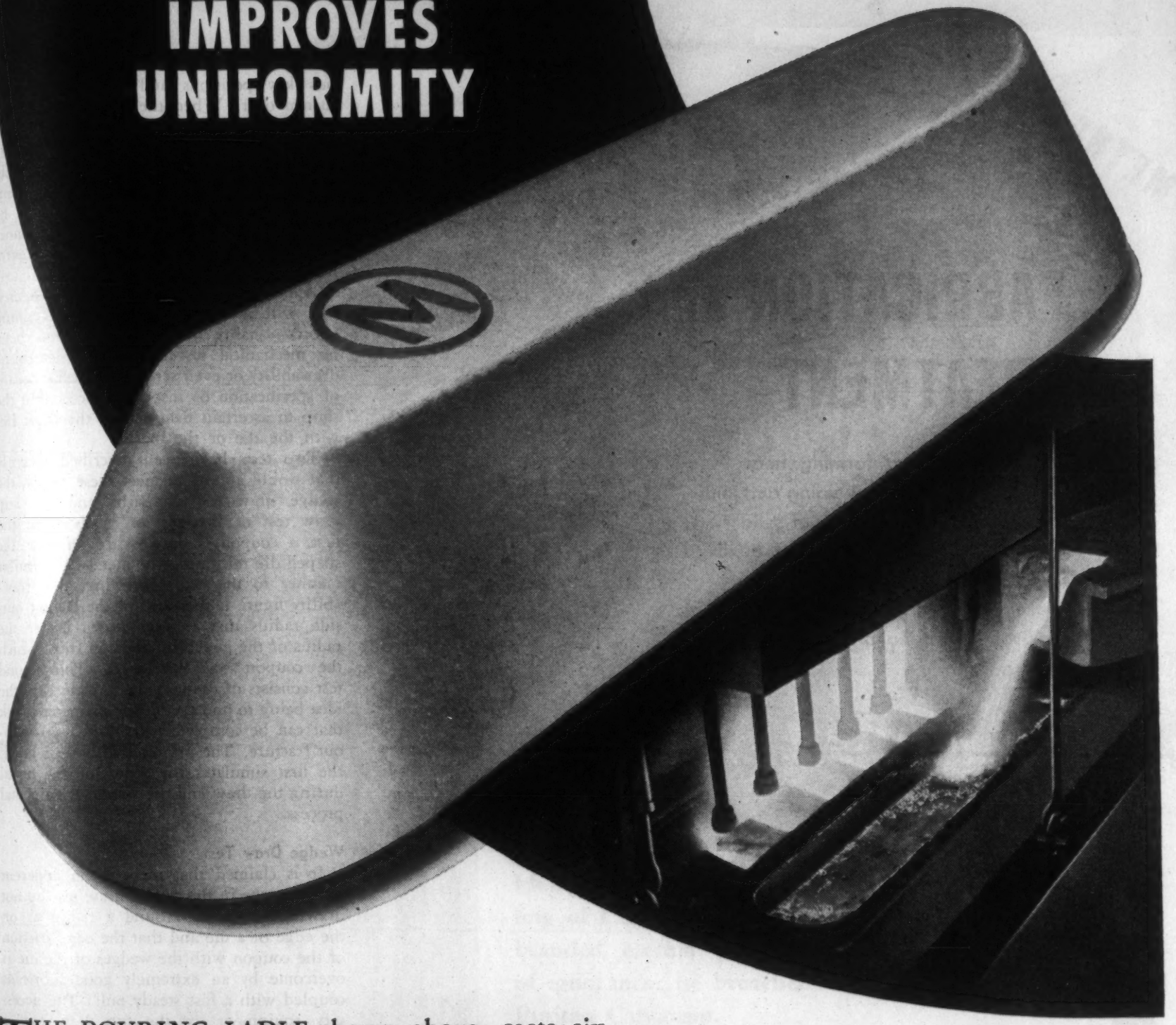
The standard type of tuyère has a nose thickness of not less than ½ in. It is the nose that has the most wear. A thickness of over 2½ in. may be employed if deoxidized copper is used. Chemically pure copper has a conductivity of 50% while deoxidized copper has 97%.

As the removal of the cause of abnormal tuyère losses may take some time, a Beaton tuyère should be used. It consists of a main water compartment and an external compartment into which is rammed a plastic refractory held in place by pegs. The refractory will withstand molten iron until abrasion has worn the nose away when the water compartment remains. This may be left in the furnace until leakage takes place. When the cutting cause has been overcome, the Beaton type is replaced by a standard tuyère.

The latest type is the Beaton Ledbetter refractory-nosed tuyère. The refractory used is a chemical neutral to working slags. Erosion is thus minimized.

—J. B. Fortune. *Iron & Steel*, Vol. 17, Dec. 1944, pp. 704-708.

FAST POURING IMPROVES UNIFORMITY



THE POURING LADLE shown above, casts six ingots at a time—the fastest casting rate in the brass ingot industry.

As every foundryman knows, when molten brass is ready for pouring, the quicker it is cast the better the casting—and the same is true of ingot.

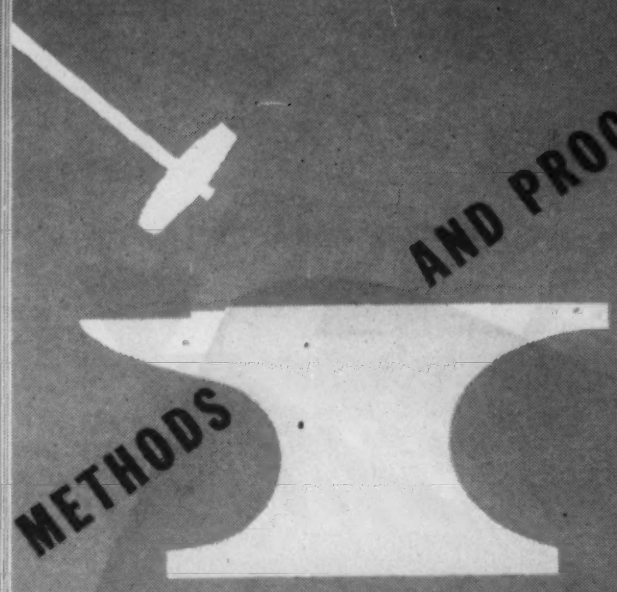
In addition, here at Michigan Smelting & Refining you get rigid laboratory control, plus fifty years of "know-how", assuring ingot metal that will eliminate for you any possibility of trouble that might come from the metal itself.

NON-FERROUS SCRAP METAL REFINERS FOR OVER 50 YEARS

MICHIGAN SMELTING & REFINING

Division of
BOHN ALUMINUM & BRASS CORPORATION
DETROIT 26, MICHIGAN
General Offices—Lafayette Building

BUY WAR BONDS



FABRICATION and TREATMENT

Machining, forging, forming, heat treating and heating, welding and joining, cleaning and finishing of solid materials. Methods, equipment, auxiliaries and control instruments for processing metals and nonmetals and for product fabrication.

Deep Drawing Technique

Condensed from "Sheet Metal Industries"

Die designing today is largely accomplished by experience. If there is any doubt as to whether a design is practical for mass production, it is advisable to make a complete small scale model and try it out under working conditions. Every pressing has a wooden model made to its inside dimensions that is used for checking the form, cutting lines, etc. A thick paper blank is used to give a good idea of how the steel sheet will lie.

Patterns for the pressure plate and pads are cast off the wooden model and built up of timber and plaster. The wooden model is also used for the punch pattern, the necessary machining and contraction allowance being put on in the form of wooden strips and plaster.

After the castings have been made, the patterns are used in Keller profiling of the punch, die, pressure plate and pads. The punch is always completed first and becomes the master.

There must be a certain amount of tryout work before production can be started. Small pieces of sheet are placed in numerous key positions and the press slowly turned over. When the tool appears satisfactory, a full size sheet is tried; very little or no pressure is applied to the first trial, the object being to obtain a panel without splitting no matter how bad the puckering. The wrinkles are gradually eliminated by increasing the pressure or adding more metal to the blank or inserting an extra bead.

Another factor must now be considered that will make or mar all the foregoing efforts—quality of steel. There has been no mechanical test that would determine drawability or even serve as a precise means of specification or inspection or enable the shop to ascertain definitely if the fault lies with the die or the metal.

Two tests have been described recently that would appear to meet these needs, the wedge draw test of Sachs and the cup draw test of Boulger and Dahle. In the first, a coupon is drawn through a wedge shaped die reforming the metal in a similar manner to the actual drawing; the drawability figure is the ratio of the largest outside radius that can be drawn under the radius of the punch for the cup from which the coupon was developed. The second test consists of drawing a complete cup, the idea being to find the largest diameter blank that can be completely swallowed up without fracture. The principle of both is good; the first simulates the action of the metal during the draw and the second is an actual process.

Wedge Draw Test

It is claimed that there is no apparent disadvantage in the wedge draw test by not drawing the metal around a radius as on the edge of a die and that the edge friction of the coupon with the wedges of the die is overcome by an extremely good lubricant coupled with a fast steady pull. The necessary equipment for the cup draw test is cheap and the preparation of the test pieces is simple. Furthermore, a kind of vernier reading of drawability can be obtained, since the results also give the percentage of successes in forming blanks of the critical size. Both tests can be carried out with small pieces of metal quite independent of production.

The requirements of a post war material can be divided into body designing, pressing, finishing, and buying. In body designing, consideration must be given to weight, strength and resonance. If too thin material is used, the drawing quality is impaired.

The strength of the present steel in the gages normally used appears to be adequate. If the metal had the faculty of becoming dead after drawing, the time and expense necessary to avoid drumming and transmission of sound would be unnecessary.

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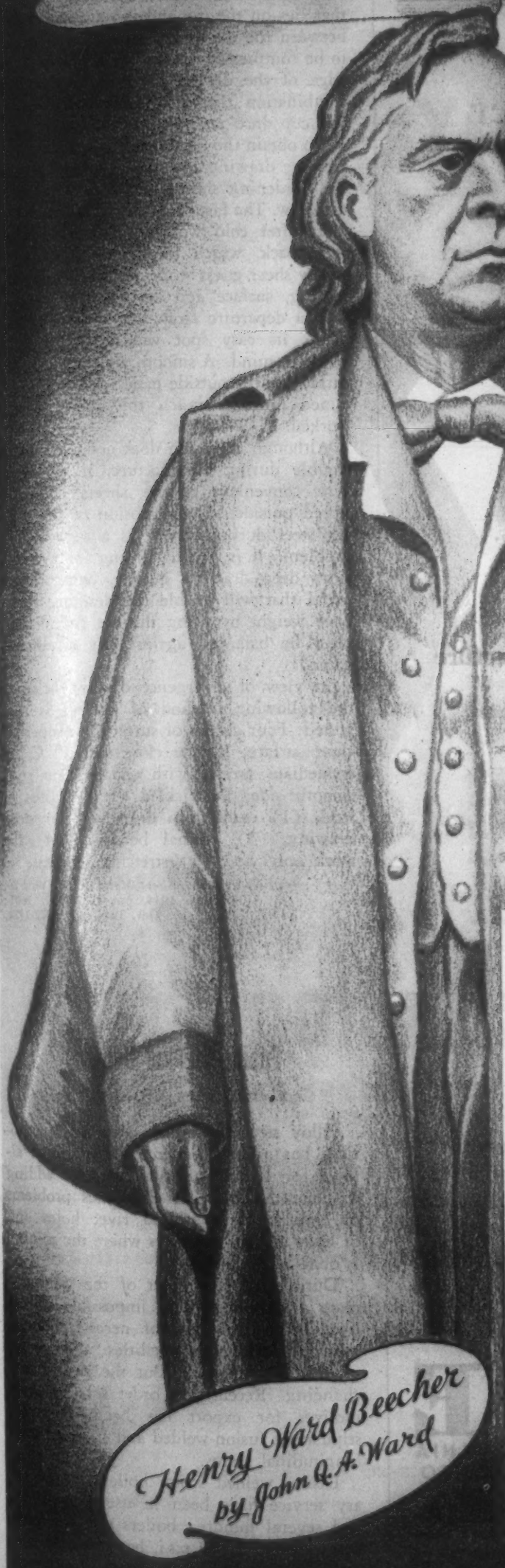

Henry Ward Beecher
by John Q. A. Ward

Henry Ward Beecher—pioneered the unshackling of Christians from the bondage of fear and branded eternal punishment as an implement of ignorance; he breached the wall of intolerant Puritan Calvinism.

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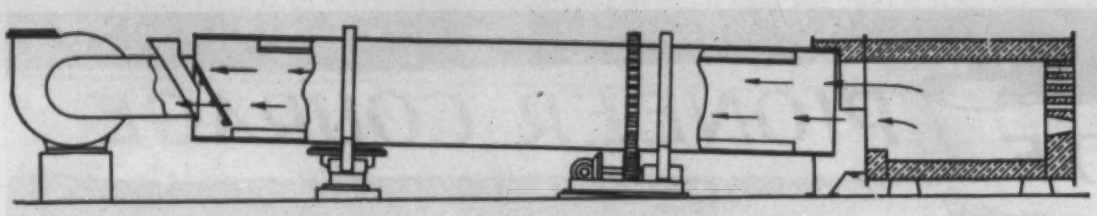

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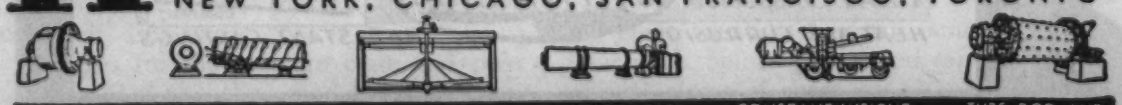


D-35

The requirements for pressing are that the metal perform in stretch, stretch and compression combined, work hardening, and state of inertness. The largest portion of metal on the face of a panel has to undergo stretch in all directions; most of the metal that lies on the die and is required to flow between the die and the pressure plate has to be compressed as it is being drawn to the edge of the die by the punch; it is this combination that makes the wedge draw and cup draw tests appear so interesting.

To obtain the ideal conditions of ductility for easy drawing and hardness for strength, the hardening should occur at the end of the draw. The faculty of the metal to remain inert after cold working would eliminate springback, which must now be allowed for by sheer guess work. Finishing includes joining, surface and corrosion.

If a departure from low carbon steel is made, its easy spot weldability must be borne in mind. A smooth, fine grained matt surface on the outside panels must be maintained however much the metal is cold worked.

Although corrosion does not cause much trouble during manufacture, it would be very convenient if the sheets could be stored outside. The corrosion of the present steel during service is a very serious problem. It is worth fighting for a cheap, extra deep drawing quality, non-corrosive metal that will enable the designer to reduce weight by using thinner gages. Cost must be balanced against any advantages gained.

In view of divergence of nomenclature, the following method of coding is suggested: Four classes of surface; A, superfine close surface; B, fine close surface; C, intermediate surface with usually one good smooth side; D, pickled. Five classes of steel, (1) extra deep drawing, (2) deep drawing, (3) normal bending, (4) flat work only, and (5) stretcher levelled.

—E. N. Salmon. *Sheet Metal Inds.*, Vol. 20, Sept. 1944, pp. 1582-1589, 1601; Oct. 1944, pp. 1772-1774.

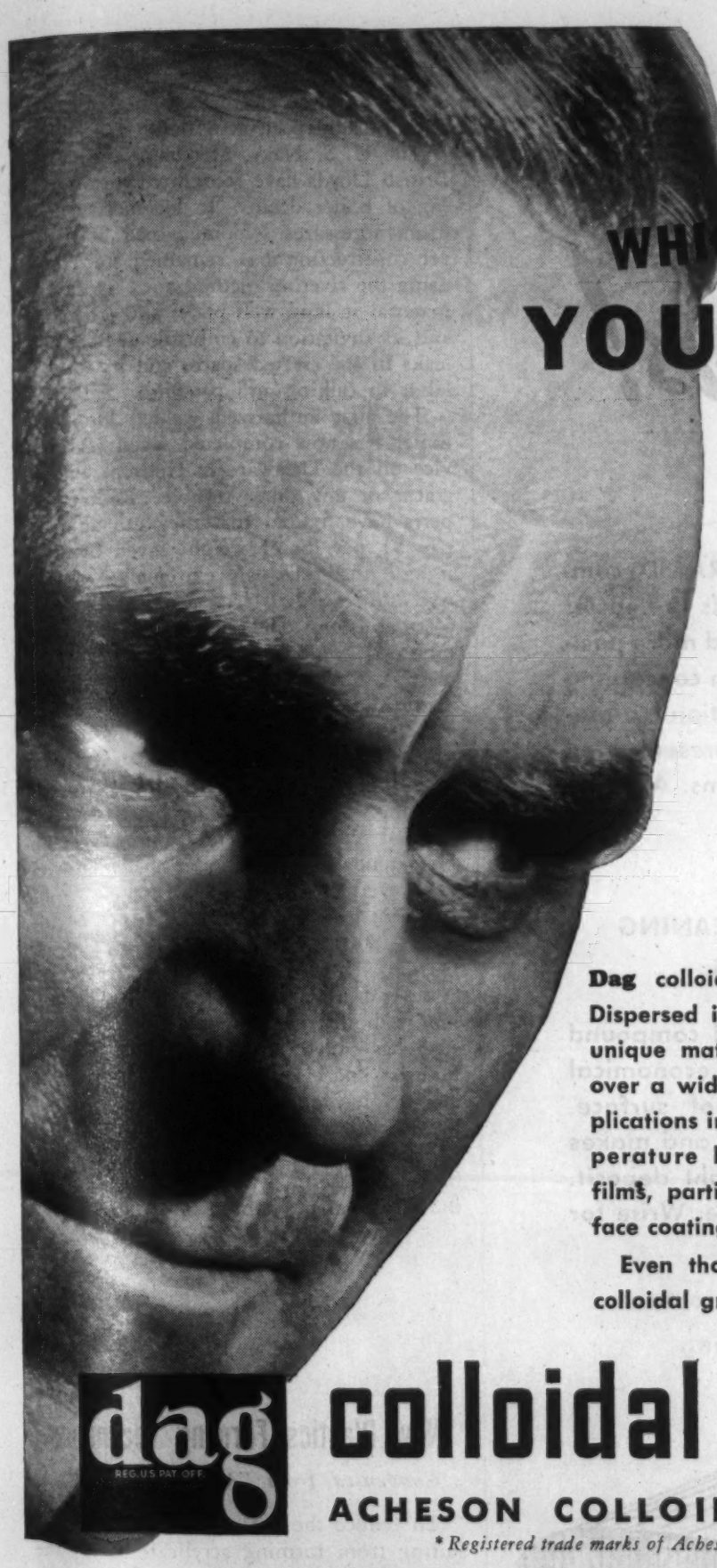
Fusion-Welded Boilers

Condensed from "Railway Age"

Alloy steel for boiler plate in locomotives has attracted attention because it allows for higher pressure without adding to plate thickness. It eliminates problems of embrittlement around rivet holes and of leaks at high pressures where the joining is done by welding.

During the early part of the war such plate and boilers were impossible to deliver because of lack of necessary stress-relieving treatment facilities and radiographic examination. But the situation is changing. Recently an order for 100 locomotives for export has been approved, stipulating fusion-welded and stress-relieved longitudinal seams.

Fusion welded steam boilers in stationary service have been in use since 1931, and several hundred boilers carrying pressures around 1,500 p.s.i. have been in successful service for eight years. In the oil refining industry the welding of pressure



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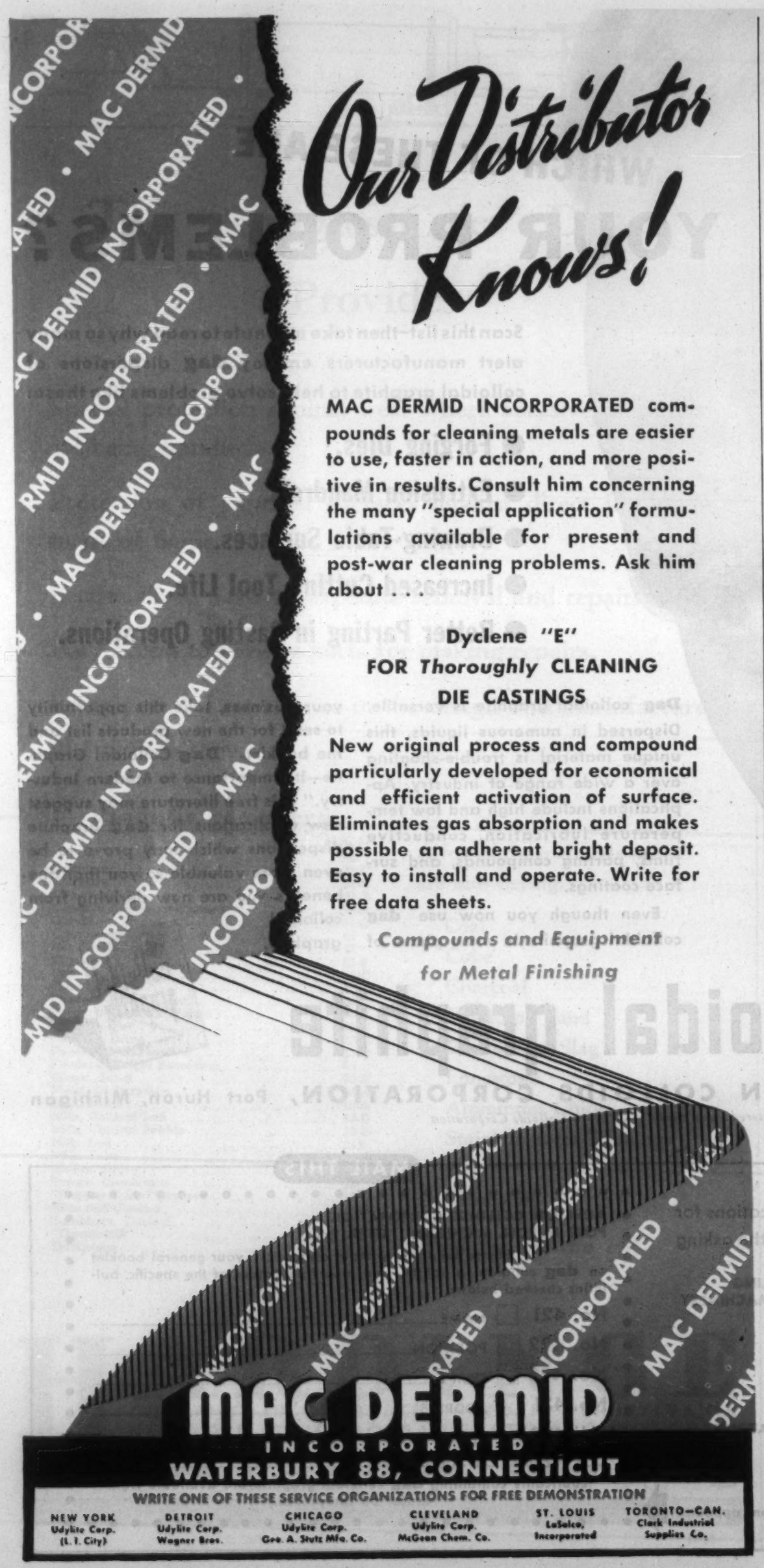

vessels has been standard practice since 1930, where pressures and temperatures far exceed those on railroads, being frequently around 1000 p.s.i. at 850 F.

The U. S. Navy, Merchant Marine and British Lloyds have recognized fusion welding of boiler drums. In locomotive boiler drums pressures seldom exceed 300 p.s.i., yet construction has remained unchanged, using the riveting method with its waste of material in laps, welt plates and rivet heads and its invitation to embrittlement through leaks in the riveted spaces and its waste of labor in calking and patching.

The first authorized welded locomotive boiler has now completed seven years service on the Delaware & Hudson, with no cracks or any other trouble. Railroad experts have figured that they can afford to pay $1 per lb. of weight saved by using lighter materials, an extremely conservative estimate. This refers only to the initial cost of fusion-welded alloy construction and ignores the much larger saving in reduced maintenance and increased efficiency through using higher steam pressures.

With a representative group of locomotives, built of plain carbon steel, riveted construction, within the first five years of operation all seams had to be cut out and patched because of embrittlement. Complete renewal of the boiler shells is necessary every seven years. Total costs for patching have averaged $8,000 per engine, with 4,800 lb. of new steel plates for repair.

Several steels are applicable to this locomotive boiler use. However, molybdenum steel has stood the test of time in the oil industry and elsewhere. One of the Diesel-electric locomotive builders recently expressed preference for A-204 steel for use in welded frames, for when these frames broke because of a wreck or severe service, the break has never been in or near a weld.

—D. R. Carse. *Railway Age*, Vol. 117, Dec. 16, 1944, pp. 925-926.

New Plastics Forming Technique

Condensed from "Modern Plastics"

To reduce the variation in thickness resulting from forming acrylic resins by the normal vacuum or vacuum and snap-back process, caused by the stretching of the material, a new technique has been developed. Using five separate steps, a flat or curved sheet of the material is made into an approximate form by bending, etc.; the joints are then buttwelded; exterior joints are carefully polished; the form is then heated, and air pressure is used to blow the sheet into the mold.

Since the material has not been stretched excessively, its strength is approximately that of the resin in the unformed condition. The reheating of the welded joints also serves to relieve any stresses that may have built up during the rough-forming.

The technique was developed as a result of efforts to manufacture a housing consisting of a cylinder closed at one end by a hemisphere. Two pieces of material were required for this form—one that became the cylinder, the other to be formed

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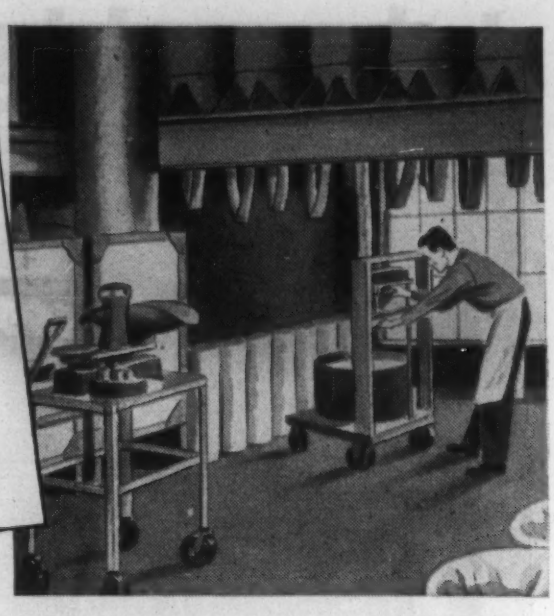

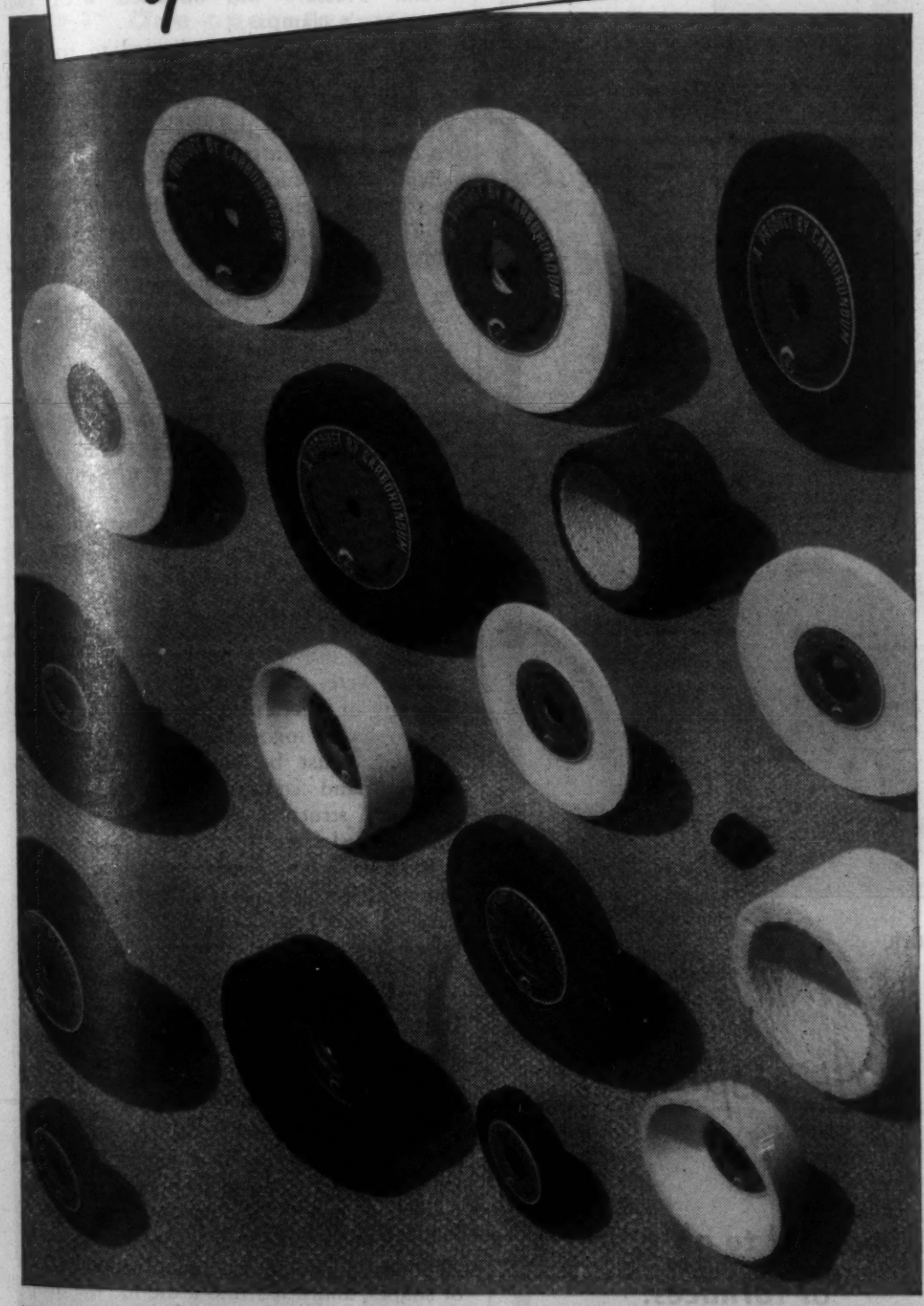

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into the hemisphere. Because of the excessive stretch in shaping the hemisphere, the cylinder was designed as the frustrum of a cone, the larger end the circumference of the cylinder, the smaller that of the hemisphere at half its height.

In forming the piece, pressure was obtained by passing ropes around the frustrum and taking up on them until sufficient force was exerted. The joint was heated by means of an electrical heating strip, allowing about 10 sec. for cooling; the strip was then removed and the edges of the resin closed under full pressure to form the weld.

A cap with turned-up edges abutting exactly on the ends of the frustrum is then welded to the first piece. Use of two semicircular heating strips accomplishes this weld. Pressure was obtained with two carpenter's clamps.

The preform is then heated to forming temperature and pushed into the finished mold. A circular wooden plug is clamped over the mouth of the mold and air allowed to enter the resin cylinder to force it to the shape of the mold. When cold, the part is trimmed, sanded, and polished.

Thickness variation of parts made by this method is very slight, even at the joint.

—H. F. Pearson. *Modern Plastics*, Vol. 22, Jan. 1945, pp. 122, 178-180.

Forging Light Alloy Pistons

Condensed from "Metallurgia"

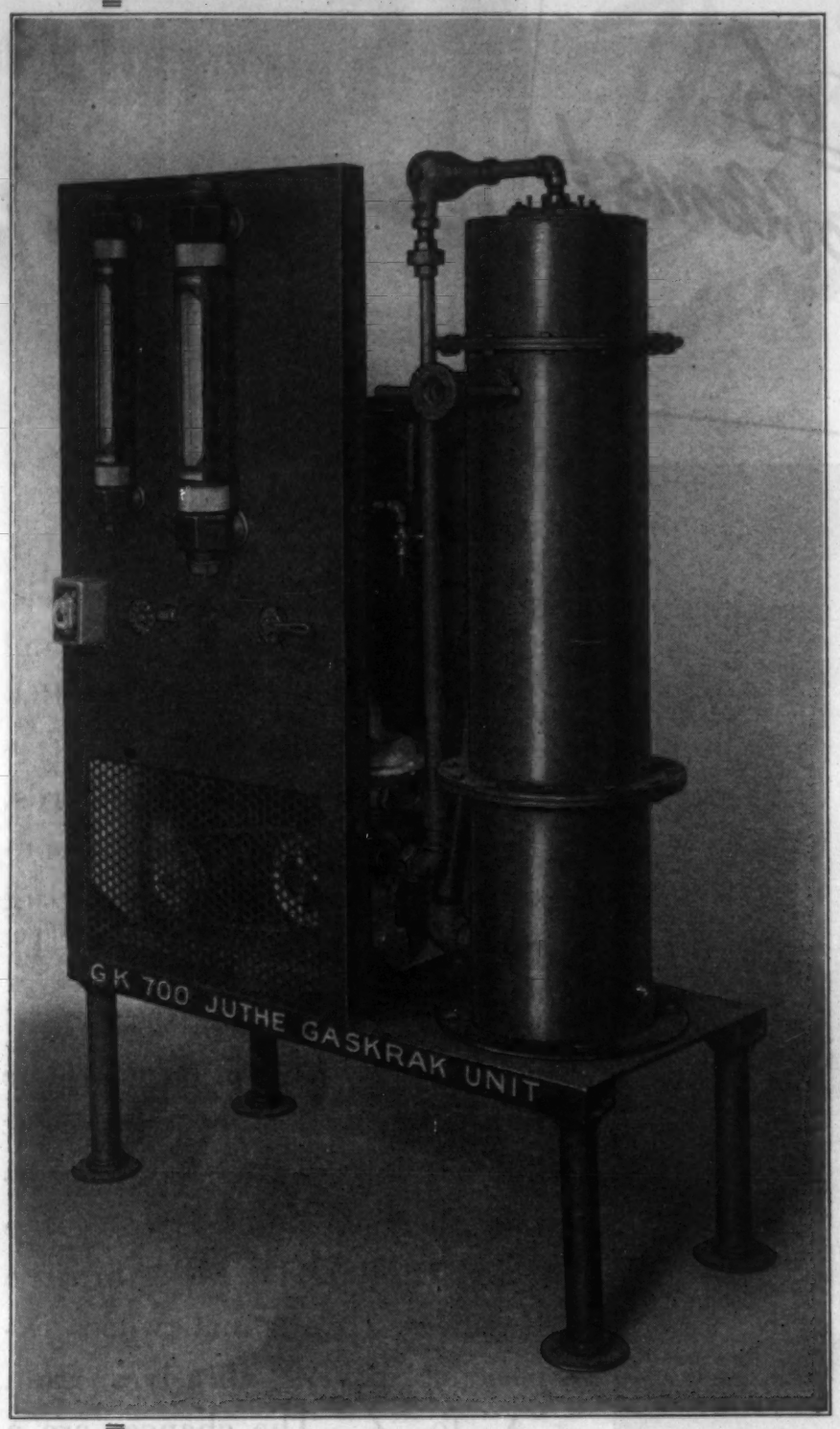
Somewhat less than 25 years ago the aluminum piston began to be generally used as a result of the search for greater engine efficiency. Cast pistons were improved, but the need for still higher physical properties led to the use of wrought material. Ingot blanks were still cast, however, and the majority of reject pistons encountered were due to faulty ingot materials.

Ingots must be sound and free from porosity and contraction cracks. A fine equiaxed structure is required. Use of water-cooled iron cannon molds is common practice, but an alternative technique involves the casting of ingots in cylindrical cans of ⅛-in. sheet steel, contained in an outer jacket which, after pouring, can be filled with water to give rapid chilling.

Current practice in this country (England) is to produce the finished piston from a blank worked by the hammering and stamping method. The ingot is first turned and cut off into suitable billets, providing sufficient material for making the solid blank form from which the piston will be made. These cylindrical blanks are then heated in an electrical muffle or salt bath, put under a drop hammer to break down the cast structure, "dummied" into a series of shapes, and fitted into a die for the drop-stamping operation.

The chief objection to production of pistons from forged blanks is the human element. Reliance must be placed upon the skill of the operator in the "dummying" operations, and uniformity is difficult to achieve.

Later developments concerned the use of pressed forgings. Experience has shown that the resultant working is much more accurate than that produced by the hammer



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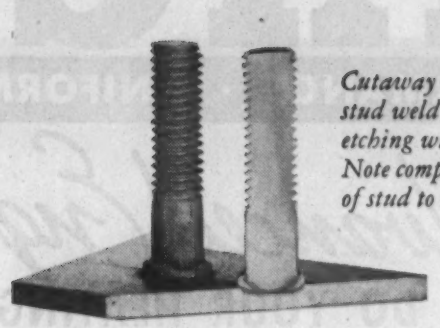

Cutaway view of stud weld after etching with Nital. Note complete fusion of stud to metal.

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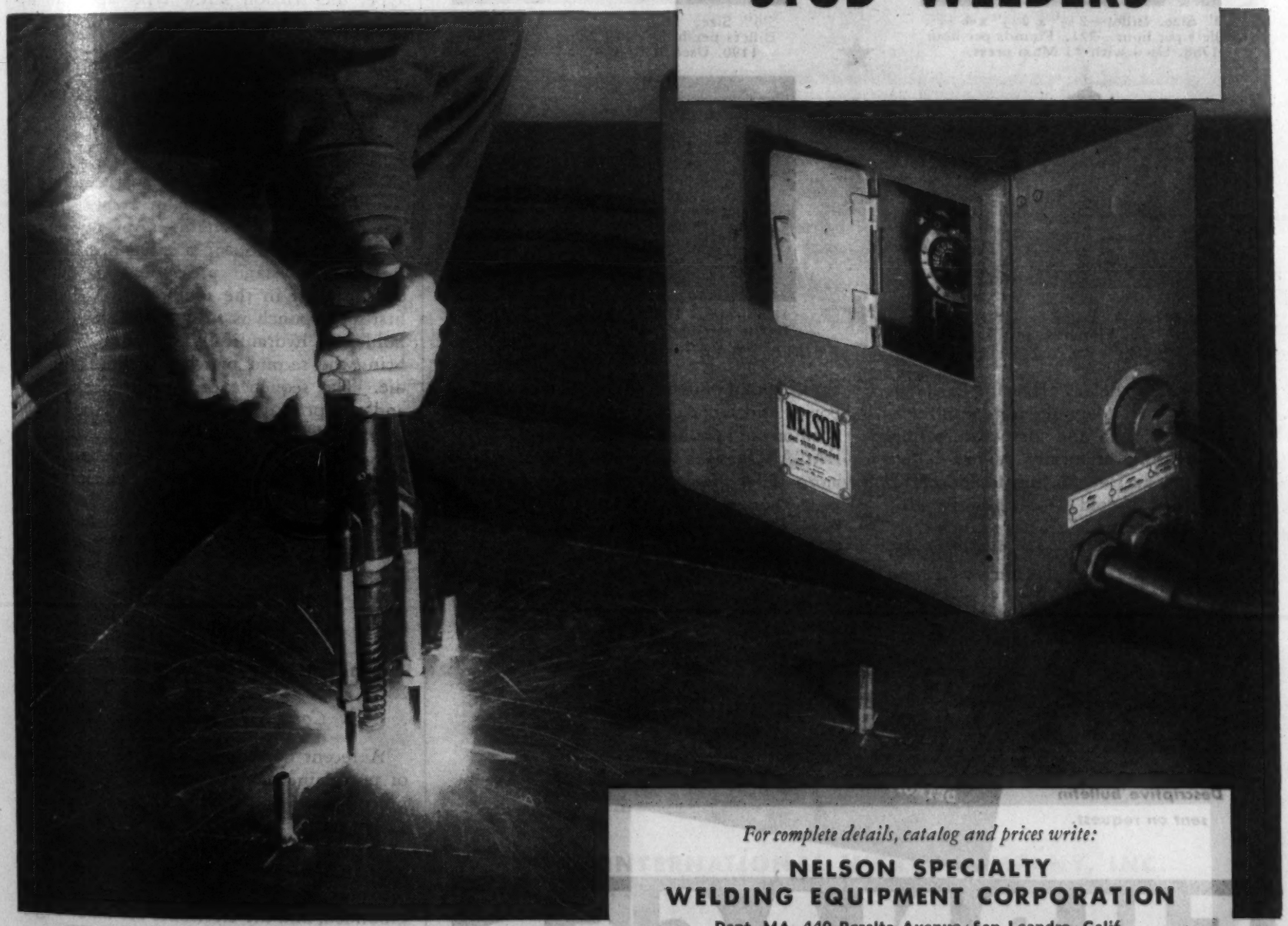

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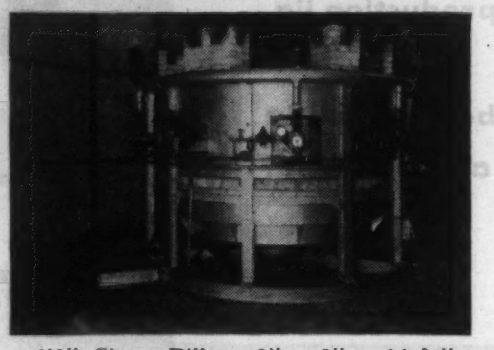

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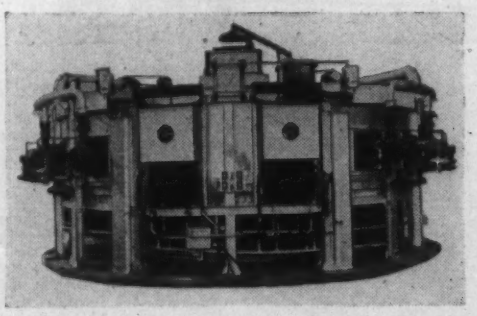

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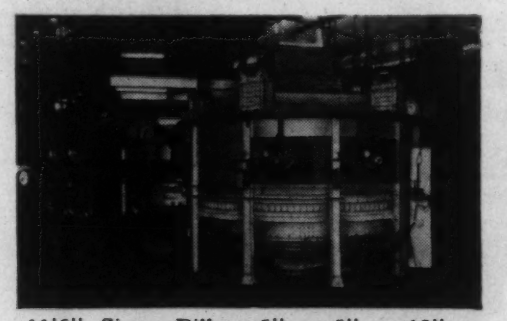

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These furnaces are available in various sizes and capacities from a few hundred pounds up to 12 tons or more per hour.

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process, and that a pressed piston can be produced to much closer limits than the drop-forged piston. Draft required on the tools is much less, the pressed piston needing only 1° of draft while that for drop-forging requires 7 to 10°. There is also a greater economy of material, since less machining is needed.

The weight before machining of a pressed piston is approximately 65% of that of a drop-forged piece. The slow squeezing process also gives better gain flow than the severe and localized deformation imparted by the hammer method.

Engineers have come to the conclusion, after studying the whole question of forged piston production, that the best methods were: (1) Use of billets cast by one of the continuous casting methods, and extruded; (2) hydraulically pressing the piston from machined blanks cut off from the extruded bar, giving greatest uniformity of results independent of the operator.

In extrusion practice, speeds vary from 2 ft. to 6 ft. per min. The flow of metal, when using the direct method of extrusion, is such that only the metal directly opposite the die aperture, the central part of the ingot, can move forward. In effect, the ingot is forced completely inside out, bringing internal defects to the surface.

Three types of presses are available for making pressed pistons, the eccentric crank type, the friction screw type, and the hydraulically actuated type. The two former require less capital outlay, are of simplest construction, and are self-contained. The last-named possesses greater sensitivity of control.

Working pressures and pressing speeds are more easily controlled. A special feature is the provision made for lateral movement of the toolholder in respect to the crosshead where certain forms of pistons cannot be produced in a single operation.

With two-stage pressing, two punches are installed in the toolholder. When the first-stage punch is fully retracted, the toolholder is hydraulically moved laterally to bring the second punch into line with the die. The sequence of the approach stroke and the pressure stroke is then carried out for this second stage. By this means only one heating of the piston blank and only one loading and unloading operation is required.

—Cecil Kimber. *Metallurgia*, Vol. 31, Nov. 1944, pp. 31-38.

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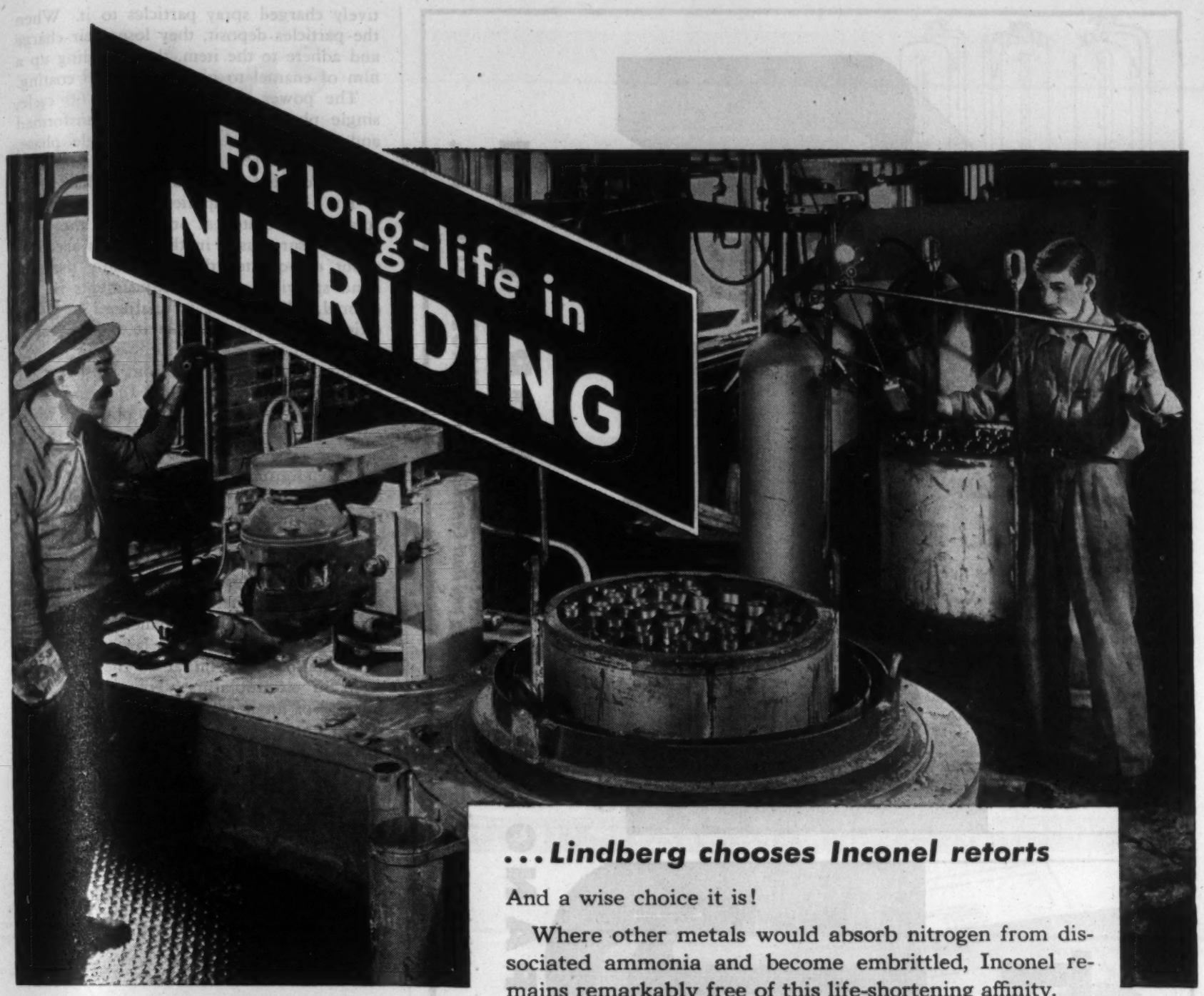
A recent development in the application of porcelain enamel consists in electrostatic precipitation of the enamel spray onto the object being coated.

A high voltage is applied to electrode wires located parallel to the conveyor. The conveyor and the work suspended on it are grounded, and the electrodes are made negative with respect to the work. When a particle of spray enters the electric field between the electrodes and the work, it requires a negative charge. The work, being positively charged, attracts the nega-



THE SUPER-CYCLONE—*a gas-fired, forced convection furnace made by Lindberg Engineering Company. Temperatures up to 1750° F. Work chamber is 38" in diameter, 54" deep. Photo shows a Super-Cyclone adapted for nitriding, from its usual task of hardening, by the use of an* INCO *Nickel Alloy retort. The Inconel retort is about to discharge its 3600-pound load of uniformly nitrided bushings with a case depth of 0.032".*

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The sum of all these properties means retort repairs and replacement will be but a small part of the operating expense of this furnace during the coming years. For, applications of Inconel in nitriding equipment have repeatedly demonstrated the trouble-free service obtained with this INCO Nickel Alloy.

Wherever you need a metal offering *high strength, ductility, chemical resistance* and *oxidation resistance,* be sure to investigate Inconel and other INCO Nickel Alloys. Their use has solved many a high temperature problem. Chances are, one of them can lick *yours,* too.

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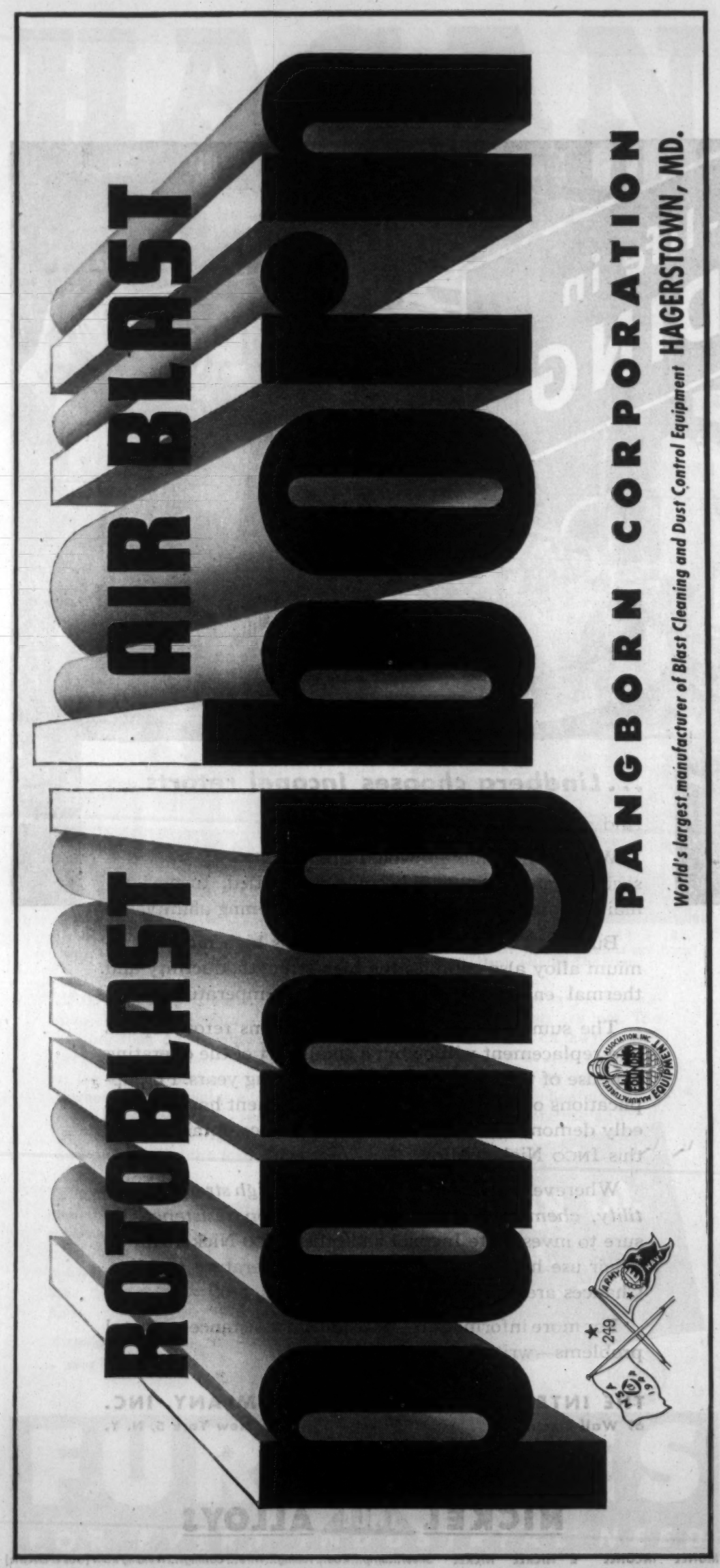

tively charged spray particles to it. When the particles deposit, they lose their charge and adhere to the item, thus building up a film of enamel to give the desired coating.

The power supply is 220 v., 60 cycle, single phase current. This is transformed and rectified to 130,000 v., single phase, half-wave current with a maximum secondary current rating of 10 milliamperes.

The spray is applied from automatic spray guns located at one end of the field. The pressures used in this process are only about one-quarter those normally used in hand spraying. Simple adjustments in the enamel, which leave it unaltered in properties after drying, enable it to be sprayed at these low pressures.

Advantages resulting from this method of enamel application are: (1) low enamel losses; (2) uniform coatings obtained without highly skilled labor; (3) one coat frequently is sufficient; (4) much brushing can be eliminated on flanged panel ware by arranging the position of the work on the conveyor to take advantage of the tendency for the electric field to change the direction of travel of the spray particles; and (5) automatic spraying of many items not adapted to automatic spraying by ordinary methods, *e.g.*, flanged panels, cylindrical items, or small articles in large volume.

Limitations are similar to those encountered in electroplating. For example, the interior of an item cannot be conveniently coated unless it is practicable automatically to insert an internal electrode during travel on the conveyor. The uniformity of a deposit on a surface possessing protrusions and depressions is in proportion to the uniformity of contour.

The process is best adapted to mass production plants.

—R. E. Helmuth. *Finish*, Vol. 2, Jan. 1945, pp. 19, 48.

Electrodeposition for Repair

Condensed from "The Iron Age"

Electrodeposition is of particular interest at the present time for repairing parts spoiled by over-machining. Small parts cheaply produced may not be worth saving, but the process becomes more economically feasible with increasing part cost.

The indentation hardness of electrodeposited metals is higher than that of the same metal as cast or annealed. Vickers diamond pyramid hardnesses of nickel and chromium, as deposited in commercial practice, are within ranges 250 to 450 and 750 to 950, respectively. Higher values can be obtained by cold working plated parts.

It has been established that under properly controlled conditions deposit and base are united by forces of atomic nature. Under ideal conditions, the force required to separate the two metals would be equal to that needed to rupture the weaker of the two. Fracture would not occur at the joint, since there is some interpenetration of the lattices and it is likely that at the interface the lattice would be strained and therefore stronger than normal.

Relative adhesion of electrodeposited coatings on metals and alloys is: mild steel,

Philqas

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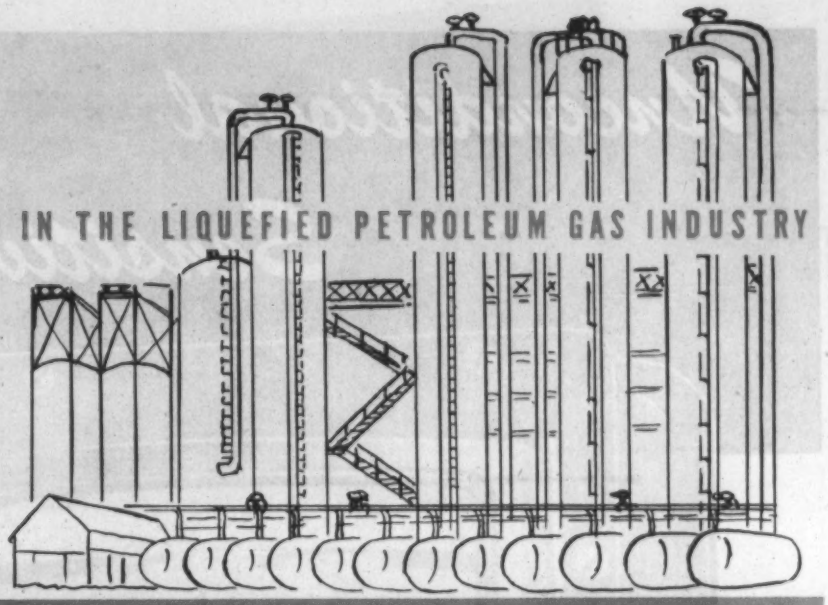

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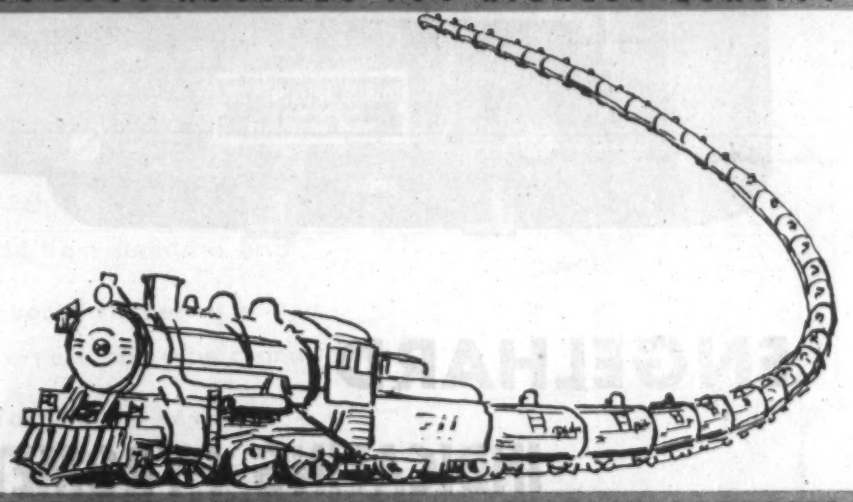

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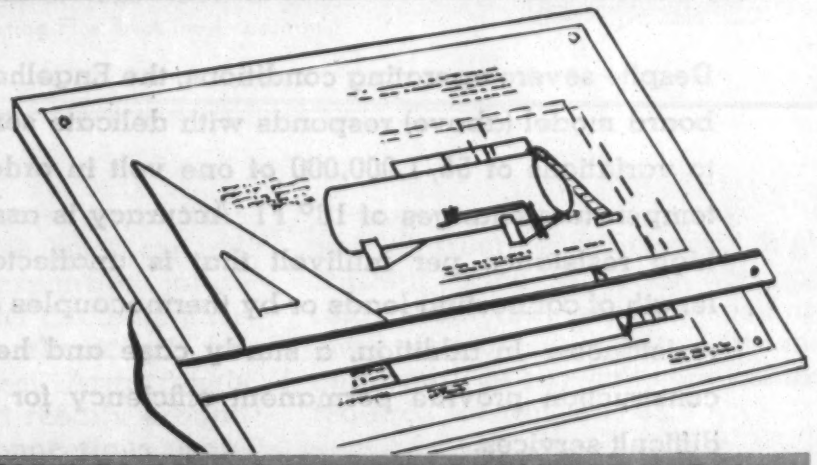

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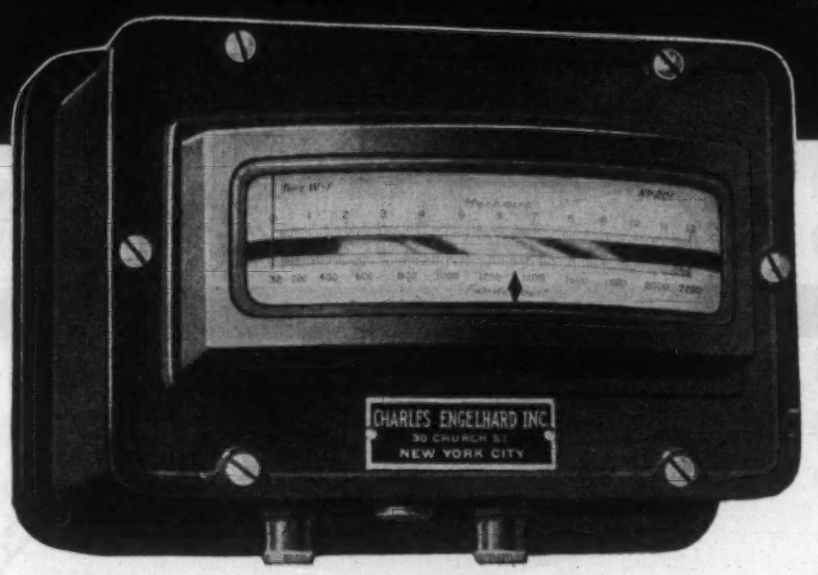


ENGELHARD

INDICATING PYROMETERS

Despite severe operating conditions, the Engelhard Switchboard model (above) responds with delicate sensitiveness to variations of 55/1,000,000 of one volt in order to show temperature changes of 10° F! Accuracy is assured by a high resistance per millivolt that is unaffected by the length of connecting leads or by thermocouples of different resistances. In addition, a sturdy case and heavy inner construction provide permanent efficiency for unusually difficult services.

Readings by direct deflection are made simply and *instantaneously* in either millivolts or temperatures. This model can be calibrated with two ranges for one type of thermocouple, or for two types of thermocouples in any combination desired. It is provided with a zero adjustment device to allow setting for ambient temperature variations.

Write for our complete bulletin today!

CHARLES ENGELHARD, INCORPORATED
90 CHESTNUT ST., NEWARK, NEW JERSEY

structural steel (low alloyed), copper, brasses (unalloyed), nickel and bronzes, strong adhesion; stainless steel, cast irons, chromium steels, nitrided steels, and aluminum alloy (some), medium adhesion; and aluminum alloys (most), magnesium alloys, poor adhesion.

Most electrodeposited metals undergo a change in volume after they have been deposited. Nickel and chromium deposits tend normally to contract, although certain nickel and chromium deposits expand. Zinc deposits normally expand.

Coatings are even in thickness only under ideal conditions. To some extent distribution of nickel or chromium deposits can be controlled. In deposition, non-conducting shields of wax or plastic sheet can be employed to prevent excessive deposit. Auxiliary anodes are sometimes necessary. Where particularly good throwing power is important, it is advantageous to choose a less well-buffered solution at moderately high pH value, with a medium current density and without agitation.

Ductility of hard and soft steels is increased by a soft deposit, and the ultimate strength of hard steel is reduced and of soft steel increased by hard deposit.

The resistance of a steel test piece to the Wohler fatigue test may be reduced by an electrodeposited coating of nickel or chromium. The chromium deposit reduces fatigue strength less than nickel.

Only nickel and chromium are in common use for building up mis-machined parts. The high hardness of chromium is of value where a hard, wear-resisting surface is required, but because of its machinability, nickel is superior for reclaiming mis-machined parts.

Due to the danger of scoring, nickel alone is not recommended for surfaces sliding in contact with steel. Chromium, or a duplex deposit of nickel with a chromium facing, is recommended.

There is no theoretical limit to the thickness of nickel which can be applied. Time and difficulty of deposition increases with the thickness of deposit. As a rule, a thickness of 0.05 to 0.1 in. of nickel or 0.01 in. of chromium are the economic limits. The average rate of nickel deposition is usually 0.001 to 0.002 in. per hr., and of chromium 0.0004 to 0.0008 in.

Thin deposits of 0.005 in. can be built up on simple shapes with a tolerance of ±0.001 in.

—A. W. Hothershall. *Iron Age*, Vol. 154, Nov. 23, 1944, pp. 47-51, 114.

Pressure Welding

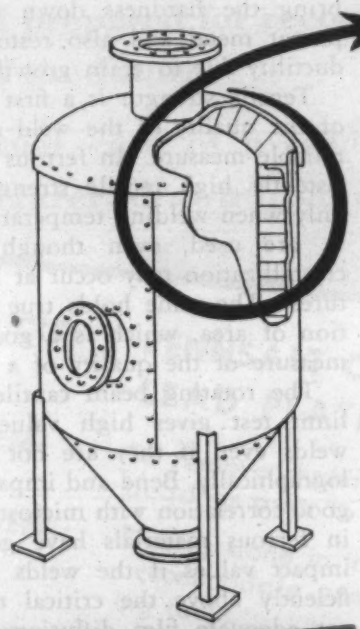
Condensed from "The Welding Journal"

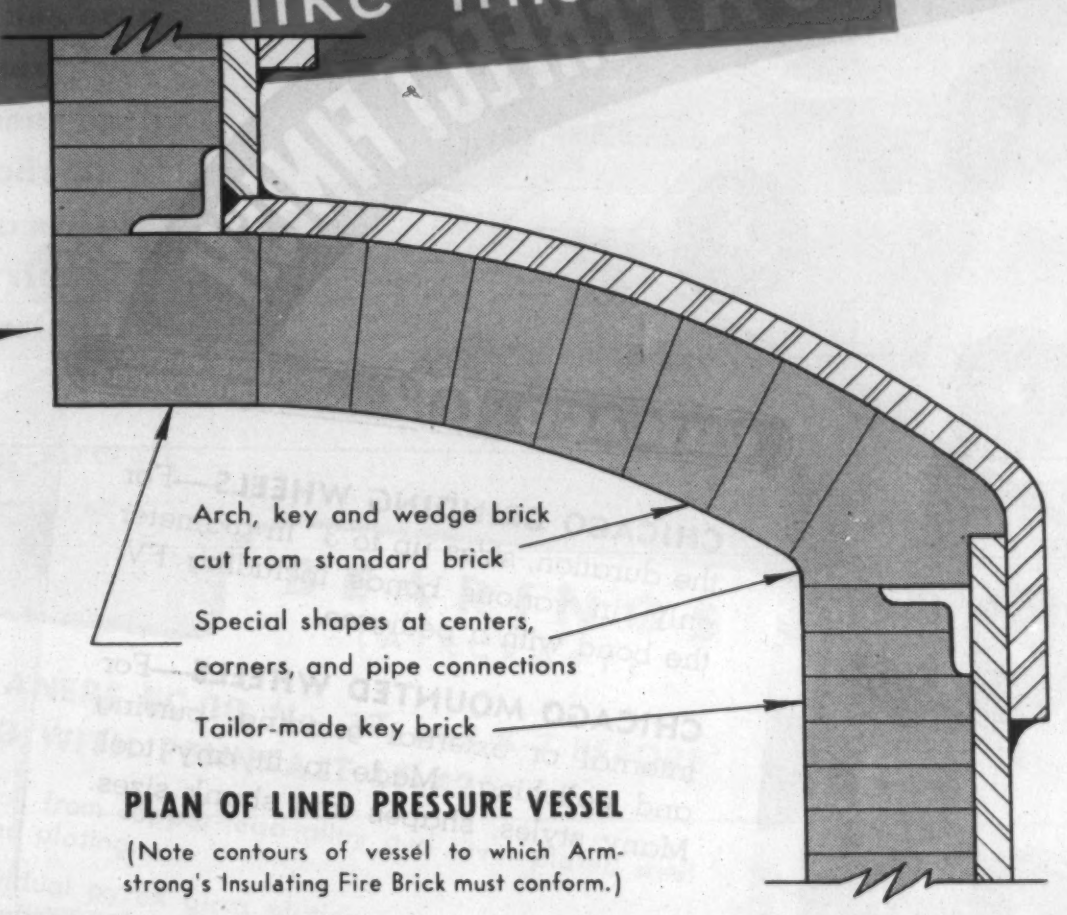
In pressure or solid phase welding, the members are bonded by atomic forces without the presence of a liquid phase at any stage of the process. Mechanical properties are not reliable indications of the value of a solid phase pressure weld. Complete interface elimination as determined by the microscope is the best scientific criterion.

The mechanism of pressure welding seems to comprise atom transfer across the interface to permit such crystallization. A hypothesis that the laws of diffusion apply to this atom transport appears plausible,

Have you an insulation problem like this?

PROBLEM **To line a high-temperature, high-pressure vessel with insulating refractories so that the shell can be built of mild steel.**





PLAN OF LINED PRESSURE VESSEL
(Note contours of vessel to which Armstrong's Insulating Fire Brick must conform.)

SOLUTION

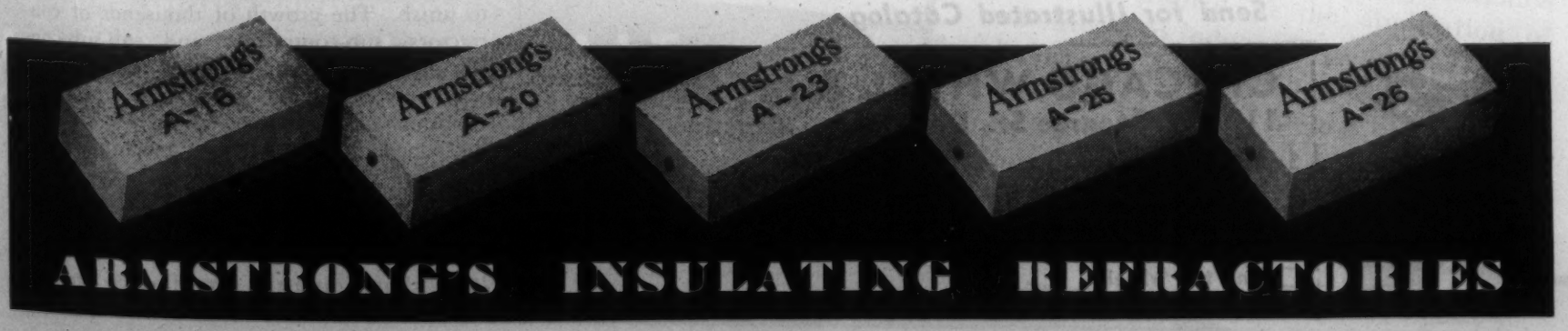
In designing equipment for new chemical processes, substantial economies can be realized if pressure vessels can be made of mild steel instead of costly alloy steel. To use this mild steel, the shell must be kept at relatively low temperatures. The refractories inside must not only withstand great pressure and heat, but they must also prevent too much heat from leaking through to the shell.

Armstrong's Insulating Fire Brick have proved exceptionally useful in this service for many reasons. Though exposed to far more heat than the shell, these brick expand so little that no expansion joints are necessary in the circumference and only a few in the length (or height) of the vessel. Armstrong's Brick can be fitted readily around complicated pipe connections, openings, and other interior contours by machining special shapes to exact specifications at the factory. Also the bricklayer can easily cut these brick to a sharp featheredge to fit irregular spaces.

All five Armstrong's Insulating Fire Brick—for temperatures from 1600° to 2600° F.—have been used for insulating high-temperature pressure vessels. They have the high insulating efficiency, high crushing strength (both hot and cold), high resistance to spalling, low heat storage, light weight, and uniformity of size and composition required for this service.

Send for Material Specifications

The "know-how" of Armstrong's engineers is at your service without obligation. Write for your free copy of "Specifications for Insulating Fire Brick," a check list for any insulating refractory material. Armstrong Cork Co., Insulating Refractories Dept., 5503 Concord St., Lancaster, Pa.



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although the necessary constants for checking are lacking. Phase change also plays an important role in effecting trans-interface bonding, although it is not required if the temperature is high enough.

Experiments have further shown the importance of the dispersion of the interface oxide film. This too may be treated as a diffusion problem. Complete dispersion in iron and steel requires 1050 C. (1920 F.) for a short time.

Temperature is the dominant factor in solid phase welding as normally practiced. Pressure degree of upset, and time are much less critical and have a minor role in theoretical consideration although they are important in practice.

Little hardening takes place in pressure welding as the cooling rates are not much greater than those normally found in normalizing. Local torch normalizing will bring the hardness down to that of the parent metal and also restore any loss of ductility due to grain growth.

Tensile strength is a first approximation of the quality of the weld although not a reliable measure. In ferrous materials, consistently high tensile strength is obtained only when welding temperatures over 1050 C. are used, even though complete recrystallization may occur at lower temperatures. The same holds true for the reduction of area, which is a good engineering measure of the quality of a pressure weld.

The rotating beam cantilever endurance limit test gives high values on pressure welds even if they are not perfect metallographically. Bend and impact tests show a good correlation with microstructure. Welds in ferrous materials have good bend and impact values if the welds are made sufficiently above the critical temperature to get adequate film diffusion, *e.g.* 1100 C. (2010 F.) Results on some non-ferrous materials followed the same principles.

—A. B. Kinzel. *Welding J.*, Vol. 23, Dec. 1944, pp. 1124-1143.

Precision Broaching

Condensed from "Western Machinery and Steel World"

Broaching has long been one of the methods of metal removal preferred by our large production manufacturers. For machining large numbers of parts down to tolerances of 0.0002 in. the broach has no peer. This method was overlooked to a large extent by many smaller plants prior to the war.

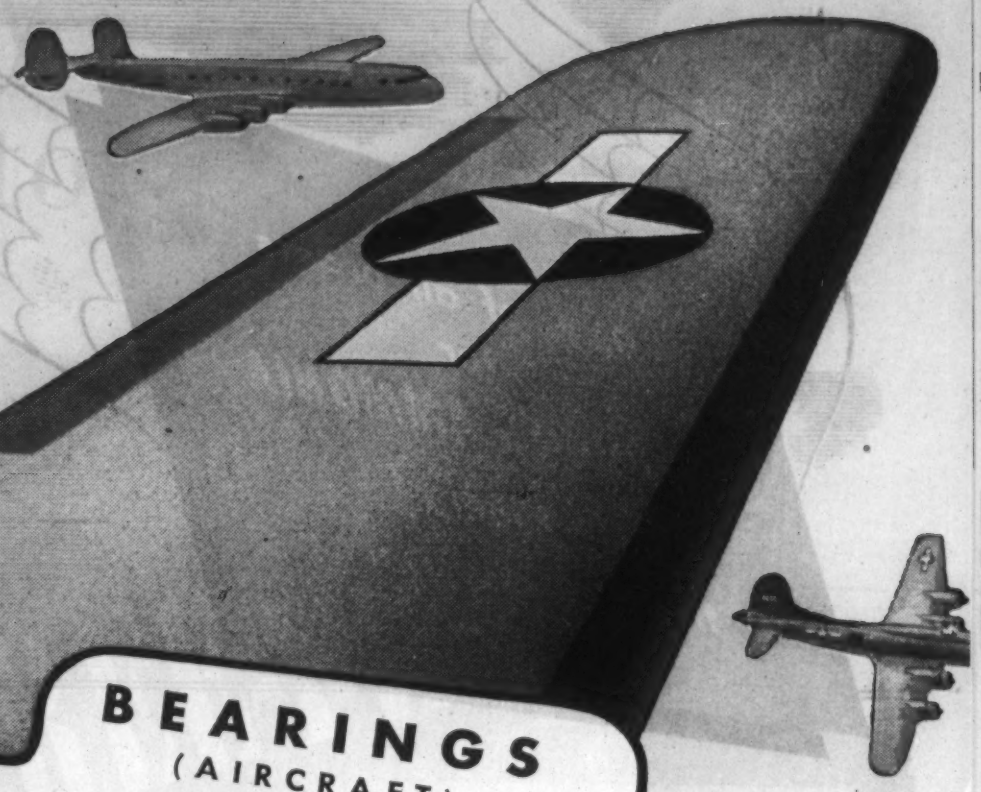
Principal makers of broaches were in the "Detroit-to-Boston" belt, far removed from many potential users. Each broach is a custom made tool, made to do one job superlatively well as to speed, accuracy and to finish. The growth of thousands of contractors, sub-contractors and sub-sub-contractors was accompanied by rapid spread of "know how," and hence more thorough adoption of broaching. Broaches are not sharpened in the ordinary machine shop, requiring special equipment and experience.

The Detroit Broach Co., realizing the need for decentralizing broach manufacture, started a plant at Los Angeles in January, 1943, thus aiding the spreading of broaching in the far west. Among examples of

Another tough cleaning problem solved by "THE PENN SALT MAN!"

THE aircraft industry has offered some of the toughest metal cleaning and plating problems in war production plants. It has been our privilege to be helpful through our products and our men in the solution of many such problems. Both the men and the products of Penn Salt's Special Chemicals Division are prepared not only for these war-time services but are equally well prepared for reconversion and the problems of the future.

Here is an actual case of a leading aircraft engine manufacturer, drawn from our files:



BEARINGS (AIRCRAFT)

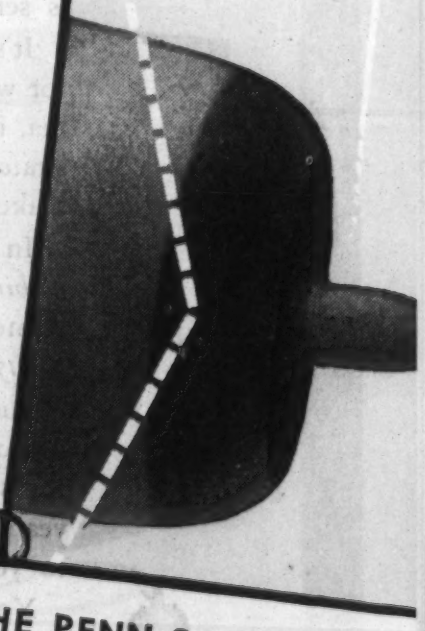
PRODUCTS USED: PENNSALT CLEANERS EC-10, No. 37, and K-7 BEFORE LEAD PLATING WITH PENNSALT LF-42

PROBLEM: To remove slushing oil from copper-lead alloy and silver plated steel bearings prior to lead plating.

EQUIPMENT: Plating done in individual pyrex glass plating tanks, large enough to accommodate one bearing. Conventional soak and electrolytic cleaning tanks.

OUR METHOD:
1. Preclean with Pennsalt EC-10 (solvent dip) followed by spray water rinse.
2. Soak clean in Pennsalt #37, 6 oz/gal., 5 to 10 minutes, 190 to 200° F.
3. Hot water rinse.
4. Electroclean in Pennsalt K-7, 8 oz/gal., 190° F., 15 to 30 seconds—work made the cathode.
5. Hot water rinse.
6. Lead plating solution made up of one part Pennsalt LF-42 to two and one-half parts water —with glue addition. Used at room temperature, 15 amps./sq. ft., for 28 minutes, which plates .001" thickness.
7. Cold water rinse.
8. Cyanide dip.
9. Indium plate.

COMMENTS: This cycle employs four Pennsalt Products.



"THE PENN SALT MAN" FIRST A TECHNICIAN . . . THEN A SALESMAN

Penn Salt Special Chemicals Division men are well trained in the application of chemicals to industry's problems. If you have a metal cleaning problem, don't hesitate to seek the advice of "THE PENN SALT MAN." He will advise you without obligation.

SPECIAL CHEMICALS DIVISION

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Despite unprecedented demands, the shortage of help and transportation difficulties, many customers receive their shipments of Armour's Anhydrous Ammonia *within 24 hours.* That is service!

It's the kind of service *Nitriding requires*... for when a metal-treating plant needs ammonia, it needs it fast. And *sixty-five stock points* strategically located throughout the country make prompt emergency deliveries possible.

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Such unusual precautions to protect product quality as well as the unmatched set-up for service are typical of how Armour's 55 years' experience can be especially helpful to you.

You'll find Armour's Anhydrous Ammonia is pure and dry with a Dew Point of −60° F. Orders can be filled in either bottle or tube type cylinders. So for prompt delivery and product dependability, call Armour today.

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profitable broaching is multiple broaching of 0.115 in. slots in locking lugs for rifles on a 6,000-lb. Oilgear machine with single slide, 42-in. stroke.

A production of almost 1000 of these forged carbon steel parts an hour was averaged. A feature here is the ease with which any single broach of the four may be removed from its separate broach holder, without disturbing the other broaches.

Another good example is a bronze die casting, an aircraft part, receiving two broached slots on a 5-ton Cincinnati having a 36-in. stroke vertically. About 0.6 cu. in. of material is removed to an accuracy of 0.003 in. on the width of the slot being produced, 3 per min.

A cast iron refrigerator compressor body has four sides broached, two at a stroke, and is delivered finished at the rate of 85 pieces an hr., 2.3 cu. in. of metal being removed to a tolerance of 0.005 and 1' on 90 deg. angle. This Oilgear has a particularly interesting fixture, manually clamped and of the two-station index type.

In one station two sides of the part are finished, and in the other the two remaining sides, thus forming a square. Broach inserts are set at 90 deg., each row being independent so that it can be adjusted and the location of each of the faces maintained. After finishing the first two sides, the part is located from these surfaces for the finishing of the last two sides.

In these and several other cases the finish required is "good commercial." The completed surface of a broached job often rivals the finish of many polished surfaces. It is far superior to some of the results of shaving dies, and eliminates entirely the breakage of metal tips under die pressure. Where occasion demands it, broaching is delivering parts machined to 2-tenths of a thousandth of an in. in quantity production numbers.

—D. A. Nelson. *Western Machinery & Steel World*, Vol. 35, Dec. 1944, pp. 526-529.

New Contour Developer

Condensed from "Modern Industrial Press"

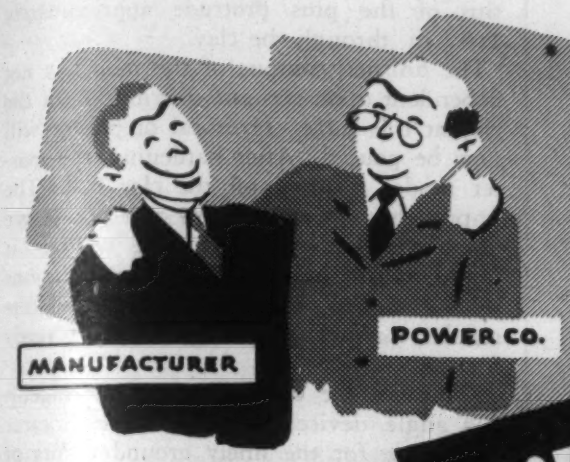
Templates are unnecessary prerequisites in the building of excellent master contours, according to the Contour Co., Pasadena, Cal., which presents the new method to the public for the first time. Any pattern, model or mock-up may be produced easily direct from loft layout alone with this developer in from 40 to 45% less time than required by the conventional templates. It produces difficult contours for punches, dies, gages, checking fixtures and jigs. These inexpensive plaster or Hydrocal contour patterns are accurate and may be quickly checked by any standard method, passing most critical inspection.

It is easy to learn the new technique. Three-dimensional contours are quickly constructed from a loft layout without templates. Male or female contours are equally well produced. Die positions or relative planes are obtained by tilting the loft layout to the desired angle.

This layout is securely clamped horizontally to a loft table. It is positioned to a desired reference line on the loft table.

NOW . . . RESISTANCE WELDING AT

Near Unity Power Factor (less KVA)



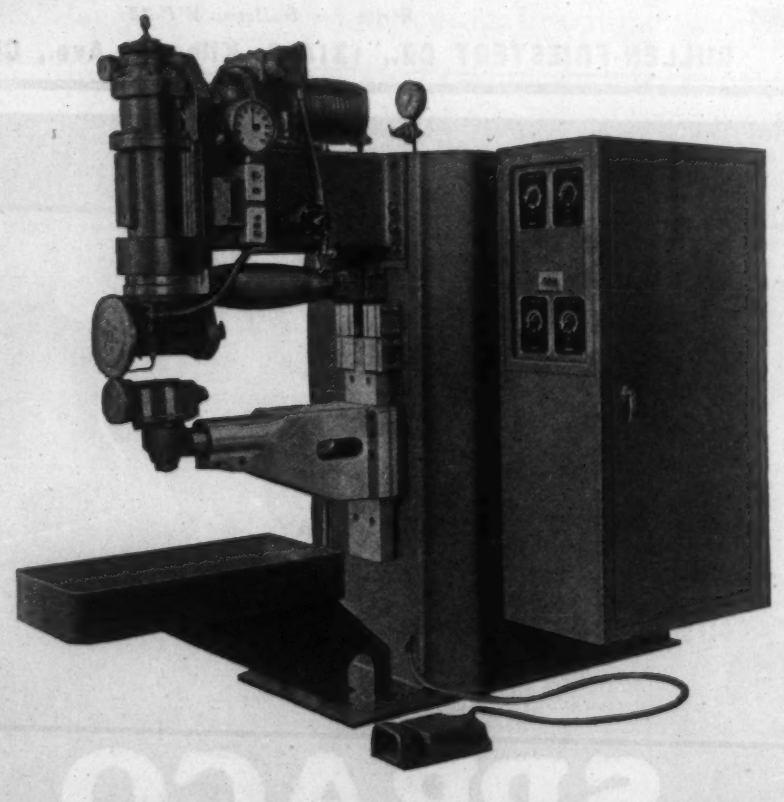
"THREE-PHASE"

Manufacturers and power companies have long been at odds over the problem of supplying power for heavy reactive loads. Particularly in the case of heavy duty resistance welding of steel, power suppliers have often found it necessary to place a ***demand charge*** on the manufacturer.

One reason for this is that conventional welders must utilize the comparatively high frequency alternating current in their secondary circuit. High frequencies mean high reactance, with resultant operation at very low power factor — often 25% or less. Low power factor means more current must be available to meet the same demand . . . often requiring a boost in the size of distribution facilities.

Sciaky "THREE-PHASE" welders are designed to overcome this, as well as other difficulties encountered in heavy duty resistance welding. An ideal low frequency current is produced at the electrode tips by an ingenious system of first, rectifying all three phases of the supply to d.c., then reconverting to an alternating impulse. Operation is on a ***balanced three phase load*** at ***near unity power factor.***

Bulletin 204-A describing fully the Sciaky "THREE-PHASE" principle will be gladly sent on request.



The Sciaky THREE-PHASE principle has been effectively applied to heavy gauge seam welding. The machine illustrated (type PMM.2T-13) welds steel up to two thicknesses of .109" and can achieve a speed of 84" per minute on two thicknesses of .040". Transformer rating is 120 KVA at 50% duty cycle. Unit is entirely self-contained with hinged side mounted rectifier and control cabinets. Electronic controls provide adjustable on-off time, squeeze and hold time.

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Complete line of AC and DC Electric Resistance Welding Machines

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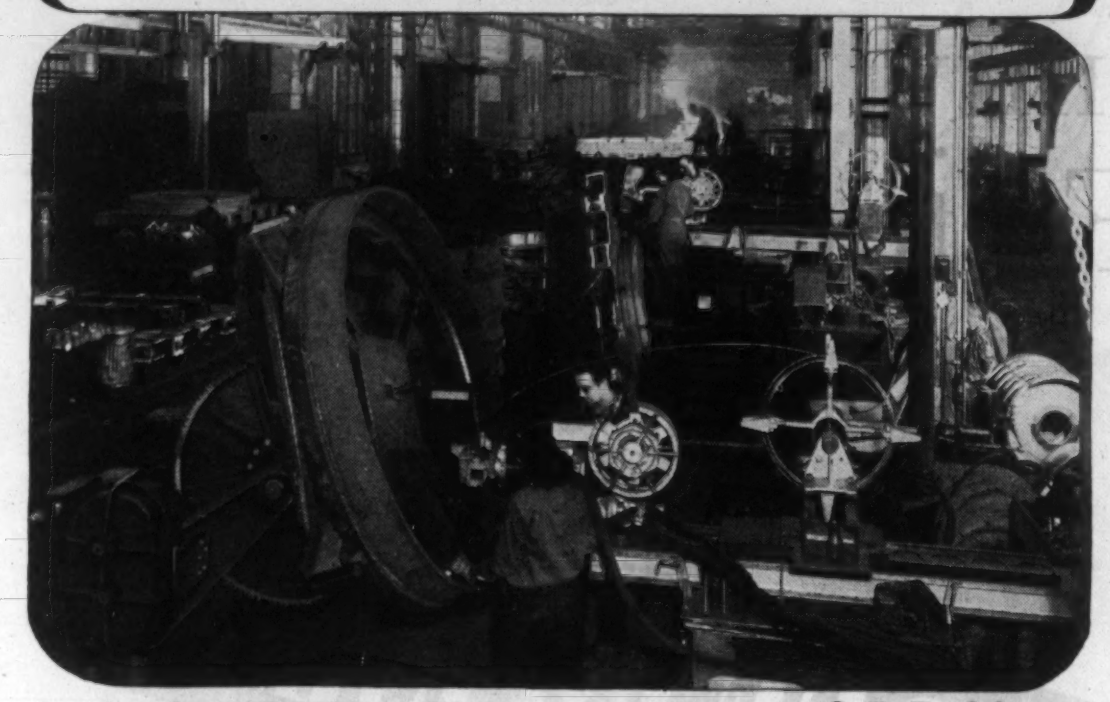
C-F POSITIONERS



Production Welding will be automatic--on C-F Positioners

Wartime advancement in *automatic* welding makes certain its wide use as a standard production method in postwar manufacturing. As now, much of it will be done on C-F Positioners, because: (1st) They permit a down hand weld on all sides with but one set-up,—rotate 360°, tilt to 135° beyond horizontal under push button control. (2nd) The exclusive C-F variable-speed drive which will give table rotational speeds from 0 r. p. m. up. (3rd) C-F positioners come in sizes and capacities for every weldment—are universal tools equally efficient for job work or the production line.

Write for Bulletin WP-22

CULLEN-FRIESTEDT CO., 1314 S. Kilbourn Ave., Chicago 23, Ill.

Pin frames are placed over the loft against stops, each pin being located accurately to the contour line with an angle held normal to that contour line. In abrupt contour changes auxiliary points are used in addition to fixed points. These highly maneuverable extra pins readily pick up trim lines at irregular intervals.

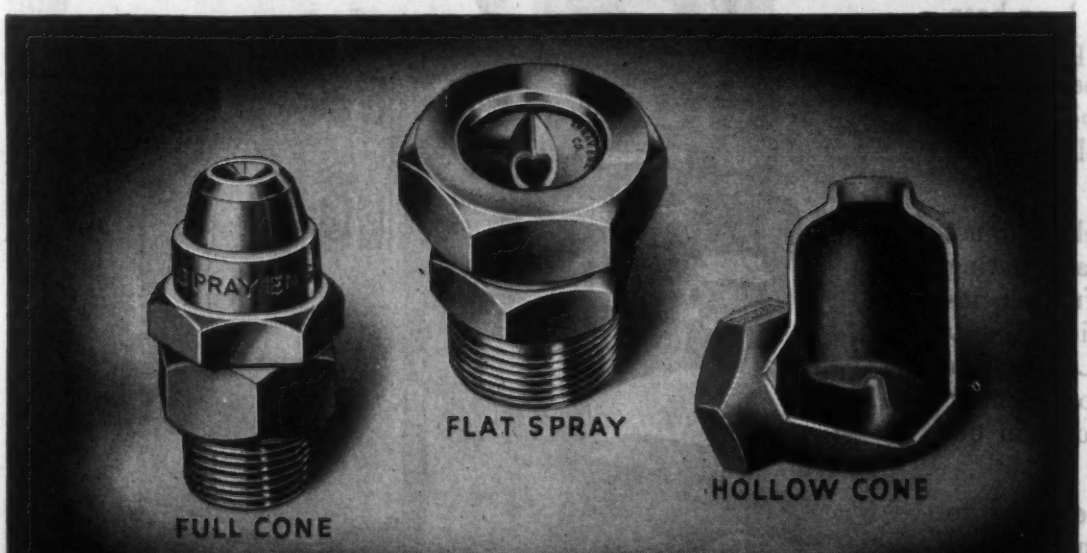
After all the pins are located and locked to the contour lines, one arranges and secures the frames at their respective proper stations in the developer base with eccentric clamps. After the complete unit is set up, wire netting is placed over disks resting on the pins and the job is ready for modeling. Modeling clay is so faired that the tips of the pins protrude approximately 1/32 in. through the clay.

The finished contour of the model is not dependent upon accurate distribution of the clay at this stage. Hydrocal or plaster will now be poured. After hardening, the master model is lifted off the clay bed. The impressions created by the pin points are filled with dark shellac. The contour is faired to the bottom of these impressions with scrapers, splines or sweeps in the regular manner. Now the model is ready for use.

Through the employment of an ingenious angle device, which serves as locator and guide for the finely ground points of the pins, contours to inside or outside of any metal thickness may be obtained, regardless of which side of metal the contour is lofted. The master contour is produced without employing higher mathematics or using measuring devices.

The steel gage disks are so placed over the pins as to allow a half-inch protrusion of the points. Absolutely identical right and left hand contours are made with one setting of the pin frames, merely by rotating the frames in the base.

—J. L. McGraw. *Mod. Ind. Press*, Vol. 6, Dec. 1944, pp. 13-14, 46.



SPRACO NOZZLES

Write for NOZZLE CATALOG *to*

SPRAY ENGINEERING CO.

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Continuous Injection Molding of Plastics

Condensed from "The Iron Age"

A continuous injection molding and extruding machine has been developed by the Chrysler Corporation for plastics. The charge is fed from a simple hopper to a heating cylinder where it is churned, then shot under worm screw pressure, which can be regulated up to 22,000 p.s.i. through a nozzle clamped to an opening into the die.

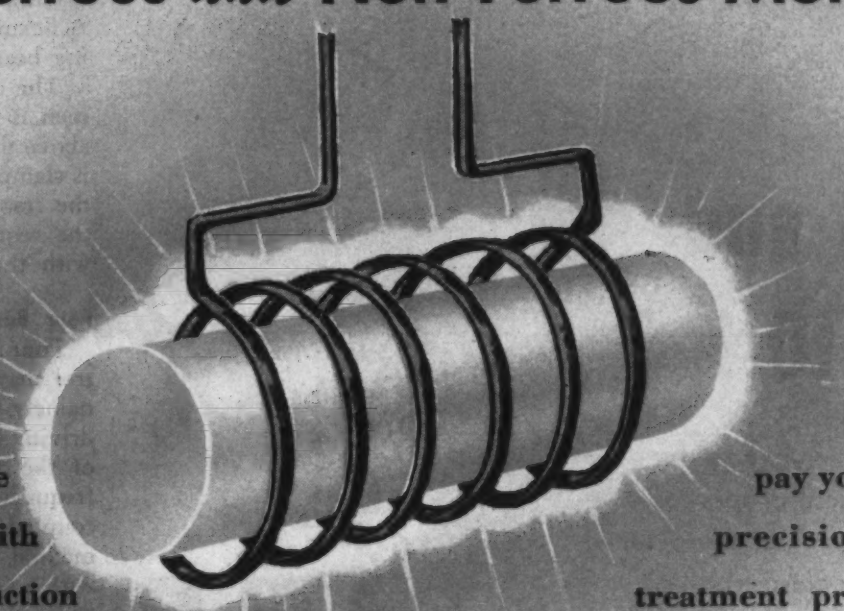
When the mold is filled, back pressure automatically shuts off the feeder reversing the worm screw. The material in the heating and feeding chambers is kept pliable and ready for the next injection.

This method eliminates flash, saves time and cuts production costs. It can be used with thermoplastics, thermosetting plastics, natural and synthetic rubber. It has produced items as large as 8 lb.

Present applications include the manufacture of rubber insulators, synthetic rubber bushings for shock absorbers, and seamless plastic tubes to launch rockets.

—*Iron Age*, Vol. 155, Jan. 11, 1945, p. 61.

New ATF *Precision*
Induction Heating Unit
for Ferrous *and* Non-Ferrous Metals



You can get exactly the treatment necessary with an ATF Precision Induction Heating Converter, provided your problem requires the use of induced Hi-Frequency currents. This scientifically designed, ruggedly-constructed converter can be operated on a production basis by relatively unskilled operators. It will pay you to investigate this precision method of heat treatment provided your everyday problems are hardening, brazing or annealing of Ferrous or Non-Ferrous metals.

An ATF Hi-Frequency Converter can speed up urgently needed War production.

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AMERICAN TYPE FOUNDERS Industrial Products Division:

Without obligation, send me complete information about the application of your Hi-Frequency Induction Heating Unit to —

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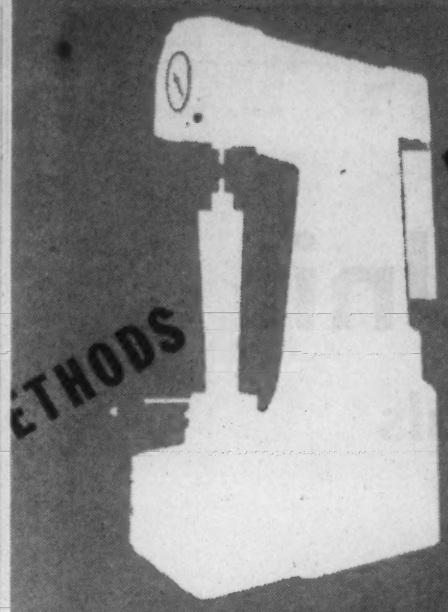


ETHODS AND PROCESSES

TESTING and INSPECTION

Testing methods and equipment for physical and mechanical properties, surface behavior and special characteristics. Radiographic, spectrographic, identification, metallographic, dimensional and surface inspection. Stress analysis and balancing. Specifications, standards and quality control.

Fatigue Testing

Condensed from "Mechanical Engineering"

Numerous types of fatigue testing equipment varying widely in almost every respect are being used. Ideally, for use by the structural research engineer, the machines should (1) be adaptable to test the fitness of the material or structural component for the use desired; (2) permit investigation of all ratios of minimum to maximum stress; (3) be simple to operate; and (4) provide for accurate determination and control of the loading. Each of the common types has inherent limitations.

The rotating beam machine fails to give data that may be accurately correlated with loading conditions other than rotating shafts. Also, it is not adaptable to a variety of specimen shapes, and a large test scatter is expected since only a small surface area is subjected to the maximum load.

In the sheet testing machine, there is again a limitation of data due to the limitations of the flexural formula used to calculate the stresses imposed. In all constant displacement machines, there is an error if specimens are subject to creep, progressive elongation or change of elastic modulus during test (as with plastics).

Lockheed designed new test machines of the direct tension-compression-controlled load type, using inertia force with resonance magnification. Operation is at constant speed, 1800 cycles per min., and the vibrating system is tuned to resonate somewhat above the testing speed to obtain load control which is not severely affected by slight changes in speed or specimen damping.

Usually, the vibrating system is tuned to give 5 to 50 amplification factor. There are both 10,000- and 50,000-lb. capacity machines that can easily accommodate a variety of specimen sizes and shapes. The driving units are rotating eccentric weights. A flexure pivot is used to attach the vibrating beam to the frame.

The distance from the pivot to the specimen is set so the system will resonate well above the testing speed; then sufficient mass is clamped onto the vibrating beam to lower the resonant frequency to a value at which the required loads may be obtained easily with the available driving force.

Four Basic Methods

Four basic methods of dynamic load control may be used singly or in combination, namely variation of (1) driving force, (2) driving frequency, (3) natural frequency of the vibrating system, and (4) natural frequency of secondary vibrating system coupled to the primary system. The first method is used on the 50,000-lb. machine with a system to change the eccentric weight while the machine is operating. The necessary equipment is too expensive for smaller machines.

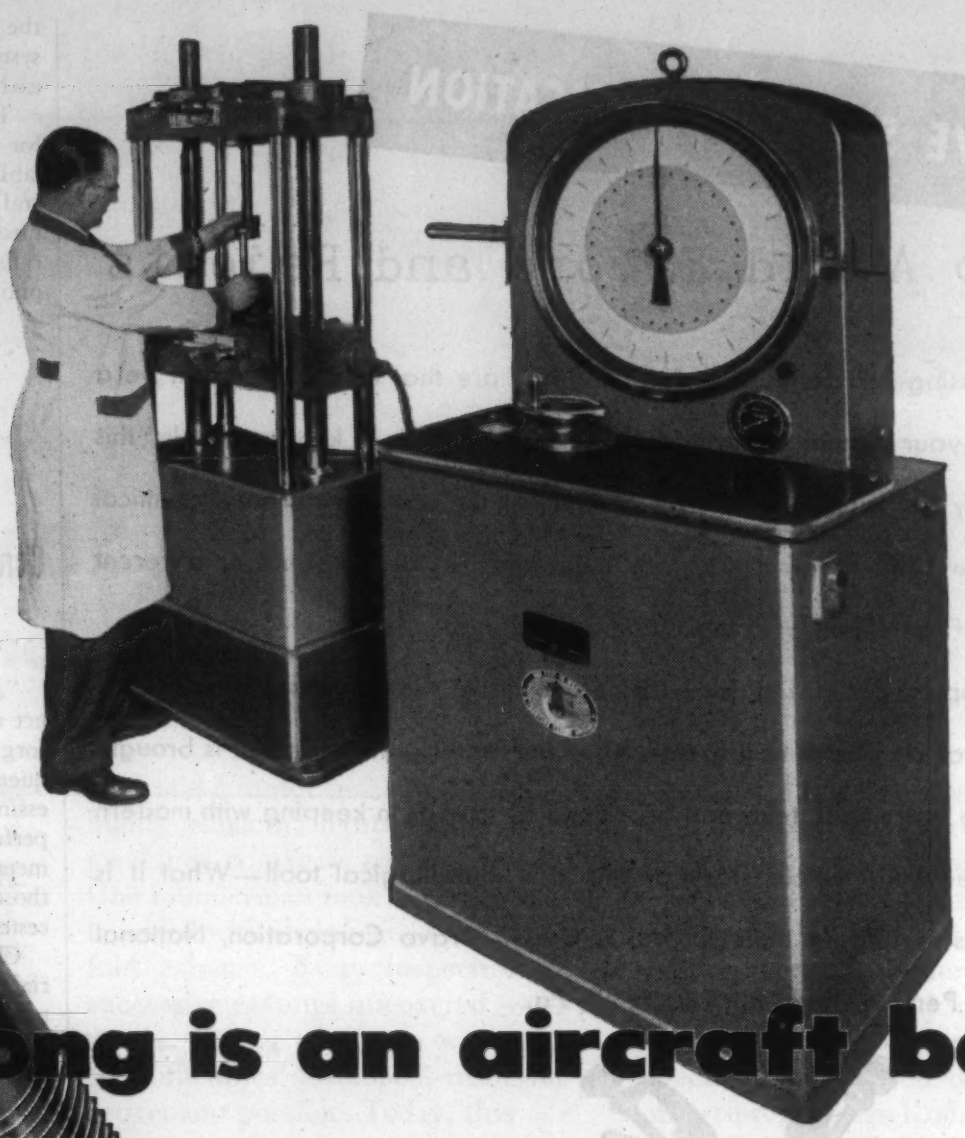
The second type of control uses a d.c. motor driven from a motor generator set. It is expensive if accurate. Lockheed uses this type only if the tests require constant attention.

The third and fourth methods are unsuitable for primary load control but are excellent for load adjustment with some coarser means of setting the approximate load. The third may be carried out by changing the mass moment of inertia of the vibrating beam, but the fourth is much more practical and gives as wide a range of load adjustment as the third.

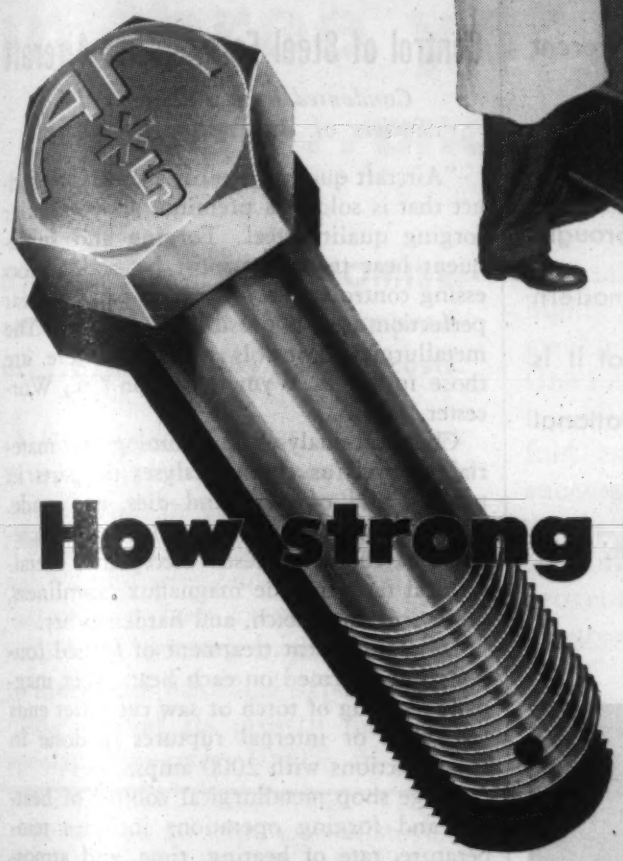
A Frahm-type adjustable vibration absorber is used on the smaller Lockheed machine, but it is tuned to operate in phase with the beam and thus increase instead of absorb the varying load. The inertia driven system can be varied by applying a static pre-load by means of a dead weight load or a spring force. The former is better for specimens subject to creep. The latter is easier to control, and facilitates resonance tuning.

The dynamic loading may be measured very accurately and dependably by installing electric resistance strain gages to measure the dynamic strains. This method is used almost exclusively, and is superior to mechanical or optical methods as inertia and friction are eliminated.

An additional circuit can be used so the dynamic load strain relationships may be plotted electrically on the screen of a cathode ray oscillograph. The cathode ray oscillograph cannot be read with as great accuracy as the modulation meter, so it is ordinarily used only for visual inspection of the loading cycle and a quick indication of



Aircraft bolts being tested on a Riehle P2 Precision Universal Hydraulic testing machine. Below --One of National Lock Company's nickel steel aircraft bolts.



How strong is an aircraft bolt?

RIEHLE TESTING

gives "National Lock" the answer

Bolts for aircraft must be plenty strong to withstand the terrific strains and vibrations to which they are subjected. At National Lock Company, Rockford, Illinois, they have been producing thousands of such bolts for 15 years to exact specifications with utmost precision and accuracy. Careful and exact testing of materials is an important part, uncovering defects before production, checking products before shipment and use.

National Lock Company has found the Riehle axiom true--*"One test is worth a thousand expert opinions"*--as have hundreds of other manufacturers. The extreme sensitivity and accuracy of Riehle Testing Machines are the result of their precision construction and assembly. Combined with the utmost simplicity of operation, their precise performance facilitates faster, more exact testing.

RIEHLE *PRECISION TESTING MACHINES*

Riehle Testing Machines Division, American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

HYDRAULIC TESTING MACHINES ◆ TORSION TESTING MACHINES ◆ IMPACT TESTERS ◆ VICKERS HARDNESS TESTERS
BRINELL HARDNESS TESTERS ◆ MEASURING INSTRUMENTS

POSITIVE STEEL IDENTIFICATION

To Avoid Errors and Rejects

If you are processing ferrous material the chances are that Identometer can be a valuable tool in your quality control plan. Equipped with a known sample, this device will quickly tell if unknown pieces are: (1) of the same or different chemical composition, if the physical structures are the same; (2) of the same or different heat treatments, if the chemical composition is the same.

Identometer operators are quickly trained to make the comparison test. Electronic timing control eliminates skill factor. After the material to be tested is brought in contact with the instrument, tests can be paced at speeds in keeping with modern shop tempos.—Read the whole story of this new metallurgical tool!—What it is and how it works is told in Bulletin 3A. Address—Dravo Corporation, National Department, 300 Penn Avenue, Pittsburgh 22, Pa.

AN ELECTRICAL INSTRUMENT FOR THE INSTANT AND ACCURATE IDENTIFICATION OF MOST ROLLED OR FORGED FERROUS ALLOYS BY THE USE OF REFERENCE SPECIMENS

the static pre-load. The electric measuring system is usually calibrated against load for each specimen.

The Lockheed machines are well suited for aeronautical research and testing to establish the fatigue strength of common aircraft materials, to analyze complex structures, to compare newly developed materials and processes, and to correlate with photoelastic analysis and static test results.

—H. W. Foster & V. Seliger. *Mech. Engineering*, Vol. 66, Nov. 1944, pp. 719-725.

Control of Steel Forgings for Aircraft

Condensed from a Paper of the Society of Automotive Engineers

"Aircraft quality" steel is a superior product that is sold at a premium above regular forging quality steel. Forging and subsequent heat treatment must be under processing controls that will assure parts as near perfection as it is possible to produce. The metallurgical controls described here are those in use at Wyman-Gordon Co., Worcester, Mass.

Chemical analyses of incoming raw material, as well as check analyses of parts in process, and of tools and dies, are made. Chemical analyses are always used to supplement hardenability tests. Acceptance metallurgical tests include magnaflux cleanliness, grain size, macroetch, and hardenability.

Laboratory heat treatment of forged coupons is performed on each heat. Wet magnaflux testing of torch or saw cut billet ends for flakes or internal ruptures is done in two directions with 2000 amps.

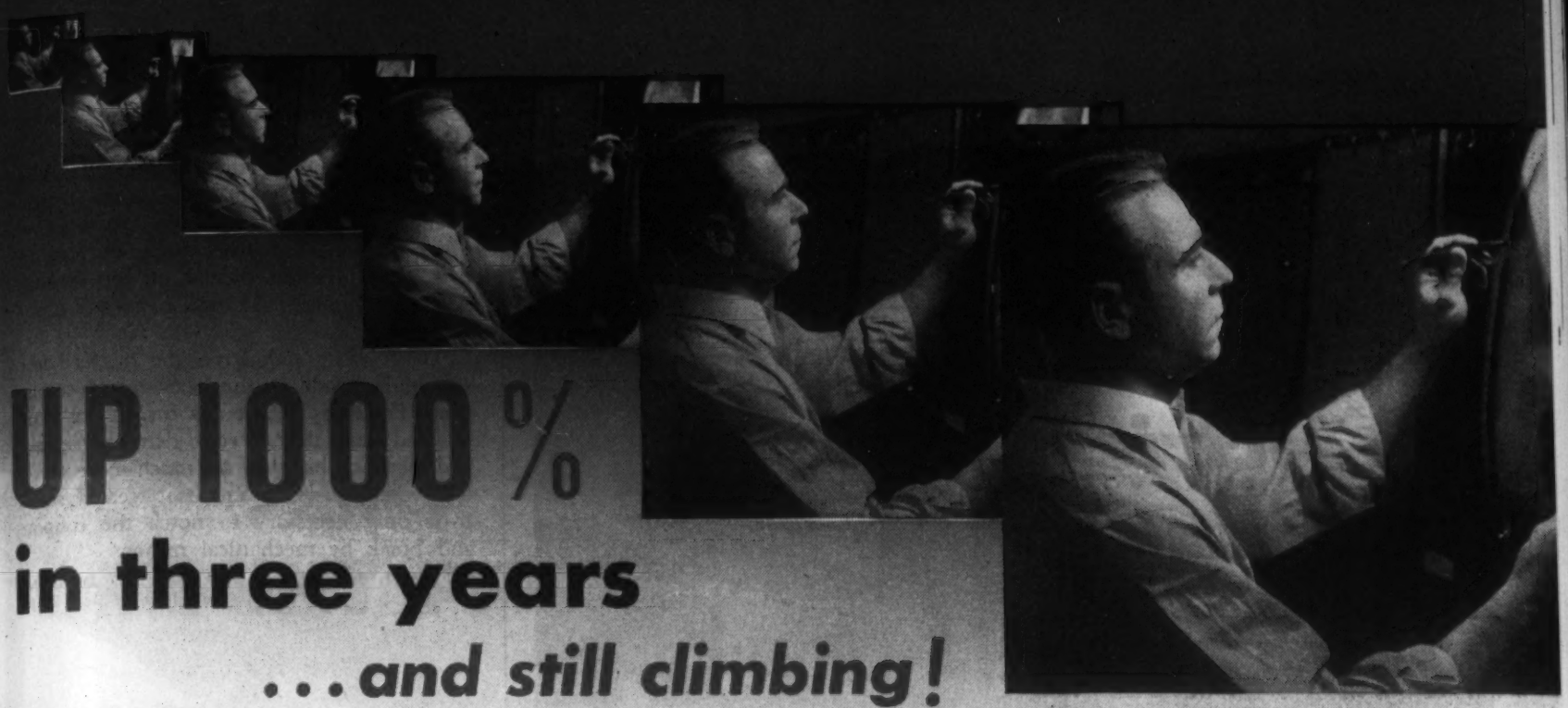
Forge shop metallurgical control of heating and forging operations includes temperature, rate of heating, time, and atmosphere control of forging furnaces, grain flow checks on new forgings, steel and heat treat specifications for tools, dies, and hammer parts.

Heat treat metallurgical control handles all controls and product testing of the forgings from the time they leave the forge shop, through the heat treat, cleaning and inspection departments, until they are finally released for shipment.

Tensile and Izod tests are made from production forgings as well as from incoming material. Increasing use of the fracture test has reduced the amount of other physical testing required. Tryout Brinell tests are made on tryouts from the various furnaces at the start of each run, and periodically thereafter. Information secured is relayed immediately to the furnace heaters so that changes in furnace temperatures may be made if necessary.

The integral fracture test, when properly designed and interpreted, is extremely accurate and sensitive. Combined with the Brinell hardness on the forging itself, it serves as an excellent metallurgical control of forgings that are to be machined into highly stressed parts. It is intended primarily as a check upon forging practice.

A considerable saving of material results from the smaller size of the fracture test piece as compared with the coupon for tensile testing. Formerly, the tensile strength



UP 1000% in three years ...and still climbing!

RADIOGRAPHY'S PROMISE: extended horizons for your product... higher quality... lower costs.

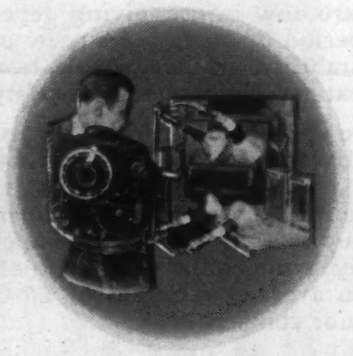
A *fact everybody knows* . . . The war gave radiography the opportunity to demonstrate its ability to determine soundness or unsoundness of internal structure—nondestructively. *A fact not everybody knows* . . . Radiography has proved itself so widely to those who have had experience in using it that its growth has been spectacular—over 1000% in three years and it's still growing.

Let's look at some case histories. One manufacturer—faced with a probable 6-figure loss when *visual* inspection of his product showed hairline cracks in metal—called radiography to the rescue. Subsurface inspection—penetrating "x-ray" scrutiny—proved the "cracks" to be harmless surface "pleats" resulting from processing . . . not affecting structural strength. Thus, potential "scrap" went into effective use, hundreds of man-hours and machine-hours were salvaged.

Again, here's how radiography acted as a process "tool": Foundrymen told a motor maker that a new, highly efficient, lightweight, easily machined crankcase *couldn't be cast*. One foundryman took a chance, was troubled with shrinkage in the manifold exhaust. X-ray inspection of successive castings uncovered weaknesses. Seeing what was wrong, as the difficulties developed, made improvement possible. Today, this one progressive foundry is the sole supplier of all of the crankcases required.

And so it goes. More and more companies are finding radiography a great help in meeting today's rigid production schedules and high inspection standards. They know that the higher quality and lower cost resulting from radiography will be reflected in increased opportunities tomorrow. Eastman Kodak Company, X-ray Division, Rochester 4, N. Y.

PHOTO LAYOUT Cuts Template-Making Time 99%: Reproduces working drawings directly on metal, plastic, other sheet materials... with photographic speed and accuracy. Reproductions can be made by contact or projection . . . with unfailing precision... great savings in time.



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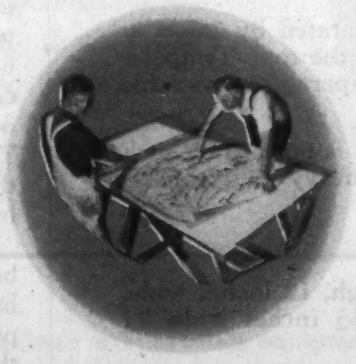


ULTRA-SPEED PHOTOGRAPHY "Magnifies" Time: Records motion too fast for the eye to follow . . . permitting study and analysis of moving mechanical parts, chemical reactions, air and liquid flow . . . smoothing production difficulties . . . saving man-hours, machine time, materials.

FUNCTIONAL PHOTOGRAPHY

Analyzes . . . Improves . . . Records . . . Reproduces

FUNCTIONAL PHOTOGRAPHY Serves All Industry: *Photo-Visuals* teach and sell, faster, with more lasting impressions. *Photomicrography* records microstructure of metal surfaces and effects of treatments. *Spectroscopy* analyzes complex substances, quantitatively and qualitatively, in a matter of minutes. *Electron Micrography* reveals detail beyond the limits of visible light, answers many hitherto unsolvable metallurgical problems. *Microradiography* probes into subsurface microstructures. *X-ray Diffraction* reveals the "invisible" by diffraction patterns, aids the search for better materials, processes. *Instrument Recording* provides a record on film for analysis and study of transient phenomena. *Stress Analysis* previews product performance.

Kodak

SARGENT

Electric Drying Oven

• Thousands of these ovens are now in use, giving dependable service. Such universal acceptance over a period of many years grew out of the satisfaction of users with the oven's durability, its dependable heating and regulating system, long service life of heating elements, and its safety features.

Heat is delivered from five elements distributed across the oven floor. The circuit is so designed as to deliver laterally balanced distribution of heat at all temperatures. A three point multiple switch prevents excessive overheating and overloading of contact points by permitting adjustment of base heat to the lowest quantity needed for any selected operating temperature. Temperature regulation is accomplished by a bimetallic controller of extreme simplicity, assuring regulation within an average variation of 1° C. Not more than 3 amperes are carried by regulator contacts.

Fast heat transfer with resultant quick drying is accelerated by inlets at the bottom provided with shutters and four outlet holes in the top. Temperature range with good regulation, up to 180° C. Higher temperatures available with slight loss in accuracy of regulation.

Emphasis on strength and durability in the construction is typified by such details as the welded frame, double insulated door and heavy gauge metal work used throughout the body of the oven.

Specifications

Inside dimensions of working chamber 10 inches high, 12 inches wide, 10 inches deep. Outside overall 17½ inches high, 13½ inches wide, 13 inches deep. Maximum power input 900 watts.

Furnished complete with two perforated shelves, thermometer having a range of minus 10° to plus 200° C in 1° subdivisions, pilot cord, cord and plug.

S-63995, for 115 volts.....$37.50
S-64005, for 230 volts..... 38.50

E. H. SARGENT & COMPANY, 155-165 E. SUPERIOR ST., CHICAGO 11, ILL.
Michigan Division: 1959 East Jefferson, Detroit 7, Michigan

S A R G E N T
SCIENTIFIC LABORATORY SUPPLIES

and yield point, with ductility as indicated by elongation and reduction of area, served as a check on forging practice, while the Brinell hardness of the forging itself was used as a direct indication of the tensile strength of the part. The fracture test now gives a more sensitive check of forging practice, while the Brinell on the forging still serves as an indication of tensile properties.

To be fully indicative, the fracture test should be made in the heat treated condition. Fractures in the "as forged" or normalized states may serve to detect extremely bad material, but they are much more sensitive when made in the heat treated state. It is only necessary to notch the coupon and break by mechanical means.

—A. J. Pepin. Paper, *Soc. Automotive Engineers*, Oct. 1944 meeting, 9 pp.

Quick Immersion Thermocouple

Condensed from "Canadian Metals and Metallurgical Industries"

Sordahl and Sosman tried a quick immersion thermocouple technique for measuring the temperature of liquid steel but concluded it was too awkward, expensive and dangerous for routine control. However, the subsequent success of Schofield and Grace led to the adoption of this method for liquid 14% Mn steel where accurate temperature control is necessary and where the vapors and fumes seriously interfere with the use of the optical pyrometer.

The equipment used is very similar to that of Schofield and Grace. The thermocouple wires are insulated in a thin twin bore silica tube that protects the hot junction. The silica tube is then pulled through a nickel tube. Considerable care must be taken to prevent the nickel tube from direct contact with the molten metal.

About 8 in. of the end of the tube is bent at right angles, threaded, and enclosed in a carbon block, 10 in. long by 5 in. diam. at the end attached to the tubing and 3 in. diam. at the other end. A fireclay protective coating about 1 in. thick is built up around the tubing from the end of the carbon block to a point where the tubing normally passes through the furnace door. The silica tube protrudes 1½ in. beyond the carbon block and is held in place partly by a small pyramid of fire clay.

The assembly is mounted on a 2-wheel buggy for ease of manipulation. A rapid balancing instrument is needed for the temperature recorder and indicator because of the rapidity with which the tube is dissolved by the liquid metal; experiments have shown that the electronic type is best.

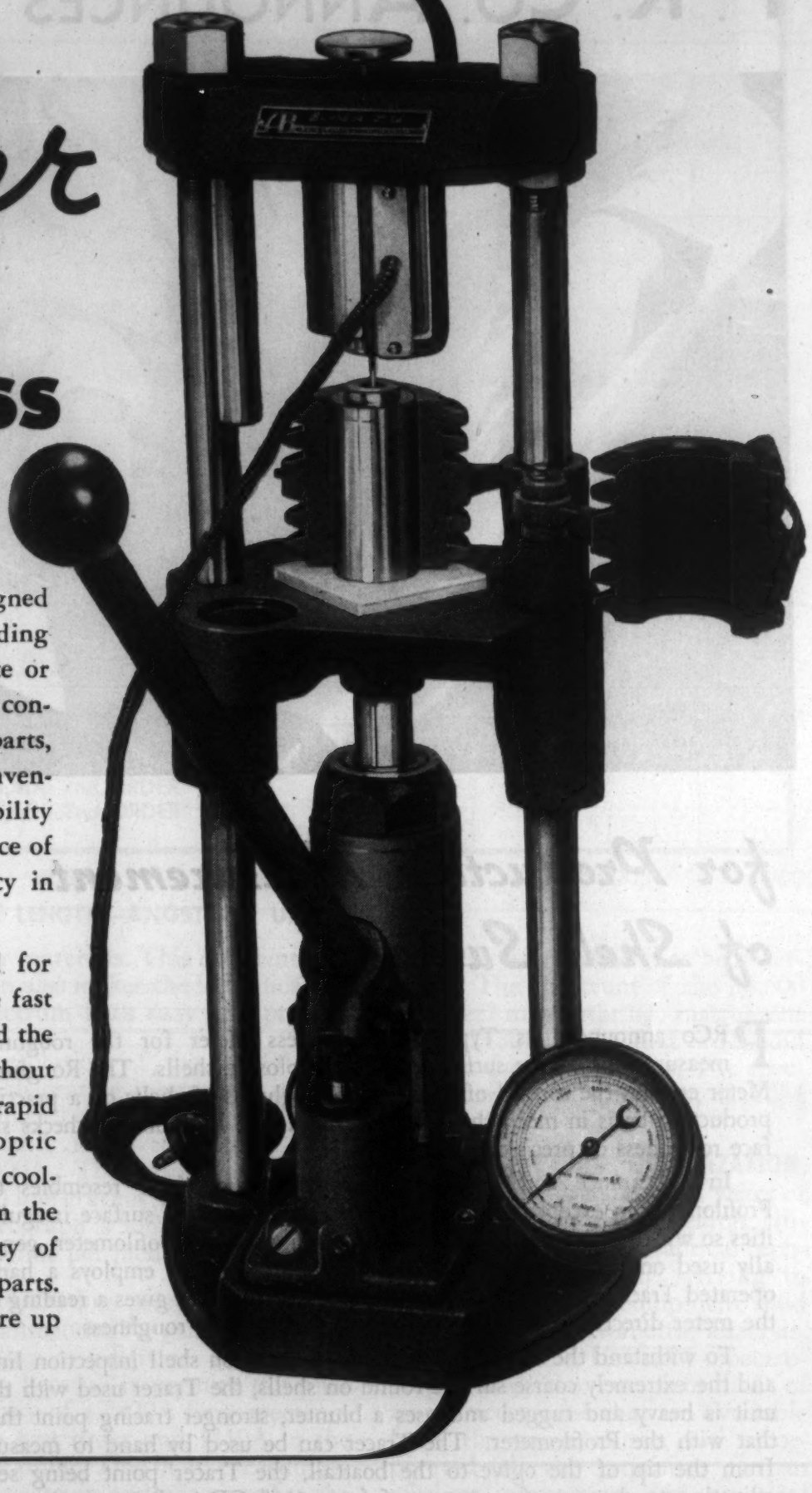
Although the hot junction is designed so it is not contaminated during measurements, it has been found necessary to renew the working end of the thermocouple at least weekly or after every 150 to 175 immersions because the vapors from the silica tubing gradually contaminate the working end of the thermocouple.

The original length of the thermocouple wire is 15 ft.; after 5 ft. have been used, the balance is returned to the supplier for credit. The silica protection tube must be

Buehler

SPECIMEN MOUNT PRESS

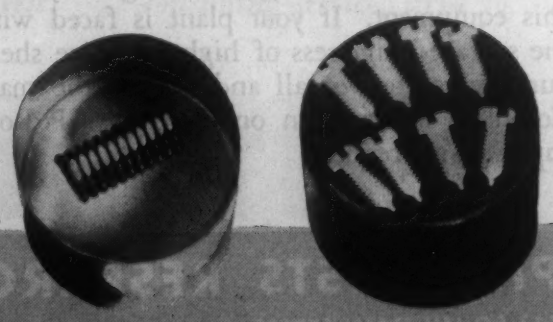
No. 1315



This new, improved model is designed specifically for the rapid precision molding of specimen mounts, either in bakelite or transparent plastic. The simple, rugged construction, without concealed working parts, offers maximum accessibility and convenience for the operator. This accessibility combined with the smooth performance of this press, permits speed and accuracy in molding specimen mounts.

Molding tools are lapped finished for close tolerance with a perfect fit. The fast working solid heater can be raised and the cooling blocks swung into position without releasing pressure on the mold. This rapid cooling permits removal of transoptic mounts in a few minutes. Heater and cooling blocks need not be removed from the press thus eliminating the possibility of accidental burns in handling these parts. This model press will develop pressure up to 10,000 lbs.

THE BUEHLER line of specimen preparation equipment includes . . . .
CUT-OFF MACHINES • SPECIMEN MOUNT PRESSES • POWER GRINDERS • EMERY PAPER GRINDERS •
HAND GRINDERS • BELT SURFACERS • POLISHERS • POLISHING CLOTHS • POLISHING ABRASIVES



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METALLURGICAL APPARATUS

165 West Wacker Drive, Chicago 1, Illinois

P. R. Co. Announces . . .

for Production Measurement of Shell Surfaces

PRCo announces its Type CP Roughness Meter for the roughness measurement of the surfaces of high-explosive shells. The Roughness Meter enables the control of the surface roughness of shells on a practical production basis in much the same manner as the Profilometer checks surface roughness of precision machine parts.

In appearance and operation, the Roughness Meter resembles the Profilometer in except that it enables the measurement of surface irregularities so widely spaced as to be beyond the range of the Profilometer, generally used on smoother surfaces. The Roughness Meter employs a hand-operated Tracer which traces the surface of the shell and gives a reading on the meter directly in terms of microinches of average roughness.

To withstand the heavy use of the equipment on shell inspection lines and the extremely coarse surface found on shells, the Tracer used with this unit is heavy and rugged and uses a blunter, stronger tracing point than that with the Profilometer. The Tracer can be used by hand to measure from the tip of the ogive to the boattail, the Tracer point being self-adjusting to changes of curvature of from 1½" OD to flat.

Because of the importance of surface roughness in the performance of shells and, therefore, in the efficiency and accuracy of our artillery, Physicists Research Company is making every effort to give prompt delivery for this equipment. If your plant is faced with the problem of controlling the surface roughness of high-explosive shells, we will be pleased to have our representative call and discuss the matter in more detail with you. Complete information on the Type CP Roughness Meter will be gladly supplied on request.

PHYSICISTS RESEARCH COMPANY
343 SOUTH MAIN STREET · ANN ARBOR, MICHIGAN

renewed after each immersion. In the interests of safety, the power is turned off the furnace during readings.

This set up may also be used to measure the temperature of molten metal in a trough or ladle. Temperature measurements have been made 30 in. below the metal surface and are regularly being made 24 in. below the surface. The quick immersion thermocouple technique is ideal for production and research as it avoids the inaccuracy of the optical pyrometer. It can also be used to determine the temperature distribution in the furnace bath and to establish emissivity constants.

—R. W. S. Freeman. *Can. Metals & Met. Inds.*, Vol. 7, Dec. 1944, pp. 23-25.

Taper Measuring Device

Condensed from "Engineers' Digest"

A new and novel taper measuring device makes it possible to ascertain the dimensions of tapered bodies by direct high-precision measurement, no computations being required at all. The chief feature of the instrument is the provision of self-adjusting rotatable feeler pads, their axes of rotation being tangential with the piece to be measured.

The instrument has a sturdy base, equipped with levelling screws. On this rests the hardened and lapped base plate of the instrument proper, which carries a vertical pillar with the travelling slide support.

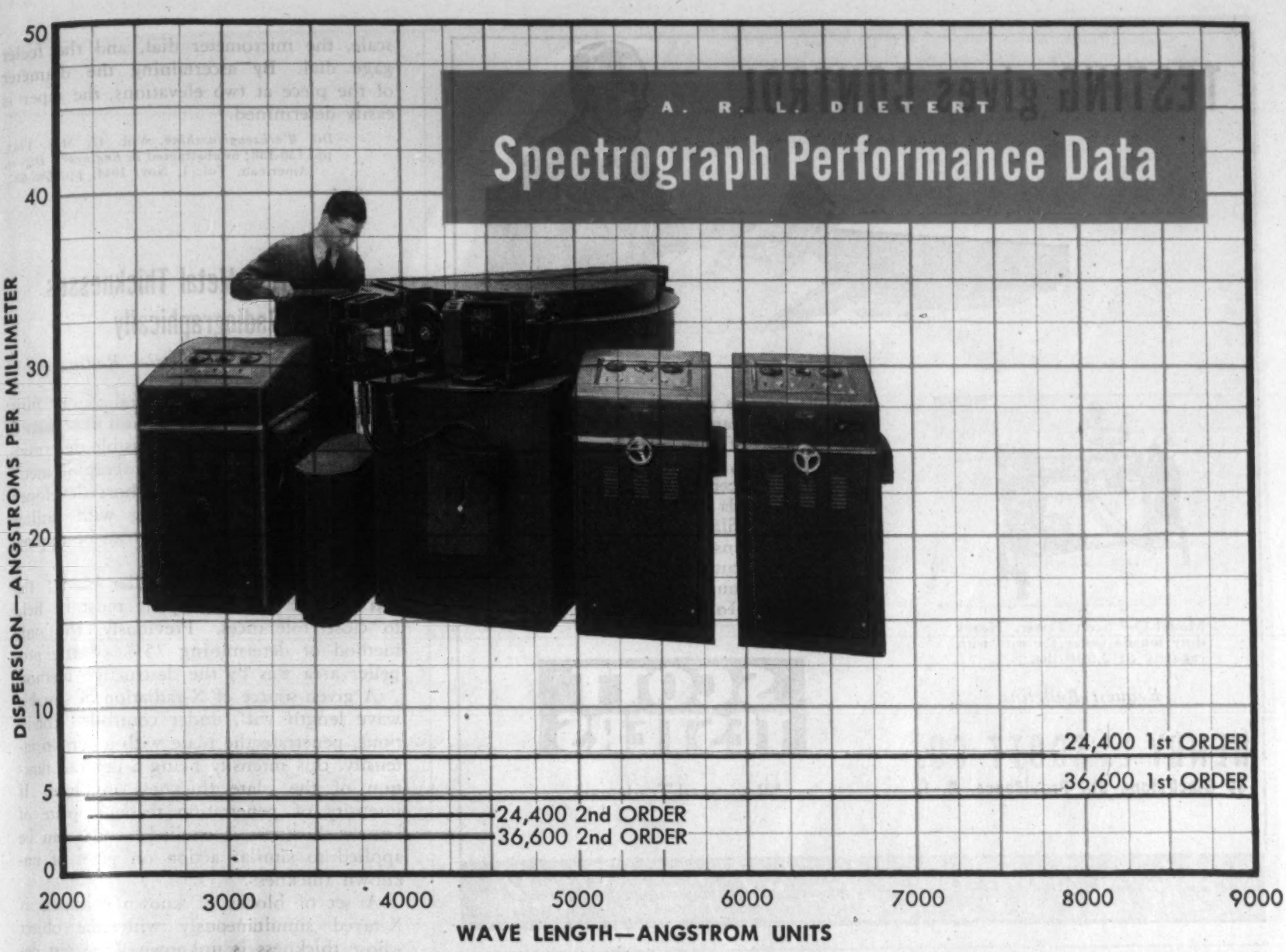
The height of the slide support is adjusted by a push-button-controlled electric motor that drives the threaded spindle recessed in the pillar, the spindle carrying the travelling nut of the slide. A micrometer screw makes the final level adjustment. The horizontal measuring slide proper is carried on the slide support by means of ball bearings and has two opposing headstocks containing the gaging plug holders, which can be clamped in position.

The gaging plug on the left is slidably coupled with a feeler lever, and the right hand side gage plug is equipped with a micrometer screw. The micrometer dial is frictionally attached to the micrometer head, permitting rotation into zero position in which it can be locked by means of a lever.

The two gage pads are half-cylinders of hard metal fitting without play into the troughs of the gage plugs, the latter being connected with an horizontal millimeter scale. The vertical position of the slide is read off on a vertical millimeter scale. A feeler gage, with dial, is incorporated in the travelling slide to work in conjunction with slip gages, which may be placed on the surface of the base plate.

If the diameter or width of a given component is to be measured at a certain level, the slide is moved to the approximate elevation by push button control and finally adjusted by means of the micrometer screw. The measuring pads are brought into contact by rotating the micrometer screw of the right hand gage plug until they touch the body, automatically adjusting themselves to the prevailing slant.

The distance between the plugs or the diameter or width of the component is then given by the readings of the millimeter



OUTSTANDING DISPERSION of the ARL-DIETERT Grating Spectrograph is shown on the above graph. This instrument is now available with either of two gratings. When equipped with a 24,400 line per inch original concave grating, a dispersion of 6.95 and 3.48A per mm is obtained in the first and second orders respectively. The same ARL-DIETERT Spectrograph, with a 36,600 line per inch original grating gives a dispersion of *4.64* and *2.32A* per mm in the first and second orders.

Observe that the linear dispersion of the ARL-DIETERT Spectrograph assures that the spectrum lines will be adequately dispersed at *all wave lengths*. Since the spectrum of steel is a complex one, the high dispersion offered by the ARL-DIETERT instrument is required for the analysis of ferrous metals and similar materials. This excellent dispersion also makes the identification of spectrum lines easy and precise.

The resolution of the 24,400 line per inch grating instrument is outstanding, being .2A in the first order and .1A in the second order at 4800A. The resolution of the 36,600 line grating ARL-DIETERT Spectrograph is 50% better than the 24,400 line per inch unit.

The 24,400 line grating instrument is recommended for general analysis, including non-ferrous and ferrous metals because it permits the photography of a 2220A long spectrum in the first order and 1110A in the second order. This in an exceedingly long spectrum and accounts for the versatility of the instrument.

THE 36,600 LINE INSTRUMENT IS *recommended for highly alloyed steels*, especially when boron is to be determined. The spectrum of the 36,600 line per inch grating instrument covers 1480A in the first order and 740A in the second order. The spectrum length, in all cases, is 12⅝ inches.

THE ARL-DIETERT ORGANIZATION, with its many installations, years of field experience, two research laboratories and staff of practical technicians, is continually striving to provide the best equipment and methods for spectrometric analysis. Into the ARL-DIETERT Spectrograph, and the complete line of mated accessories that are available from the same source, are incorporated all the requisites for an efficient, economical and practical commercial, control or research laboratory. *For information on spectrometric equipment, technical literature, or consulting service, write to . . . .*

CONTROL EQUIPMENT SAVES TIME

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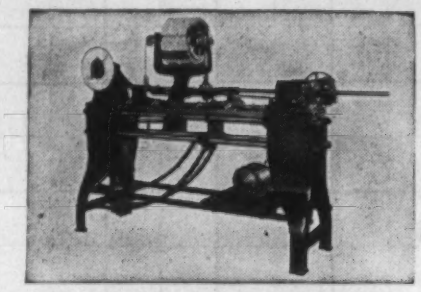
TESTING gives CONTROL



Model Q-7 Scott Tester. Heavy duty tensile tester for wire with capacity of 2,000 lbs.

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HENRY L. SCOTT CO.
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***Scott Testers provide their reading as picturized charts which are invaluable as the basis of controlled testing routine for research, purchasing, production and final acceptance. Our 65 models span the needs of wire and strip testing from finest filament to 1 ton tensile; including tensile, hysteresis, flexing, compression-cutting of rubber covering, etc. Ask about our exclusive Incline-plane Tester for the finer sizes.**

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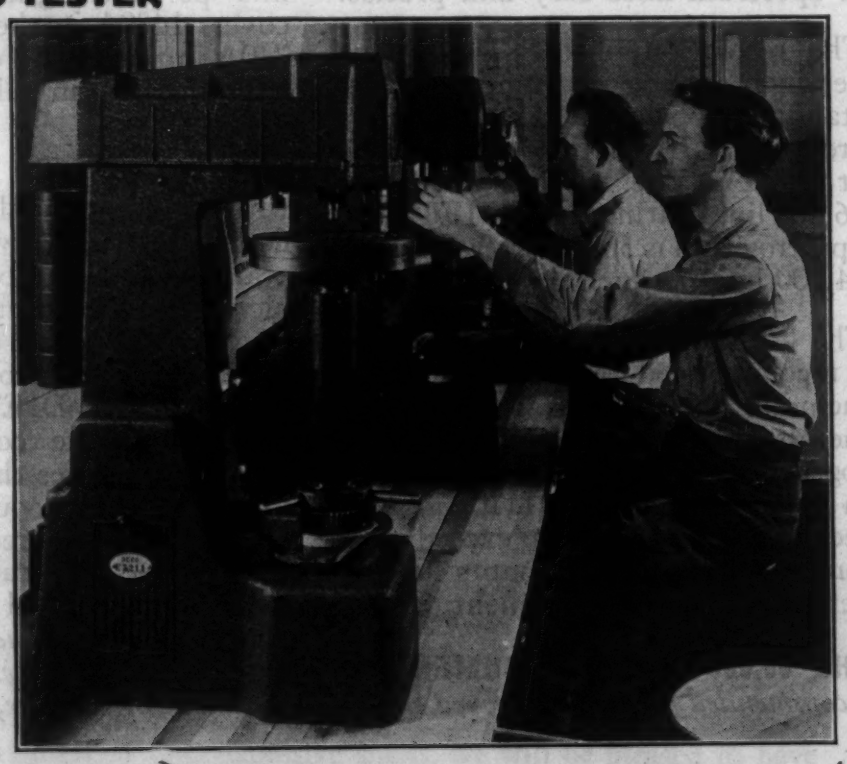
"ROCKWELL" HARDNESS TESTER



The Ohio Crankshaft Company kindly sent us the picture above, writing—"ROCKWELL Hardness Testers (one Superficial unit and two standard testers) are part of our laboratory's extensive testing equipment."

Perhaps you, also, need a light load "ROCKWELL" Superficial.

ACCO

AN ASSOCIATE COMPANY OF AMERICAN CHAIN & CABLE COMPANY, INC

WILSON
MECHANICAL INSTRUMENT CO. INC.
365 Concord Ave., New York 54, N. Y.

scale, the micrometer dial, and the feeler gage dial. By ascertaining the diameter of the piece at two elevations, the taper is easily determined.

—*Die Werkzeugmaschine*, Vol. 47, Mar. 1943, pp. 136-138; as abstracted in *Engineers' Digest*, American, Vol. 1, Nov. 1944, pp. 686-687.

Measuring Metal Thicknesses Radiographically

Condensed from "Industrial Radiography"

Improvements in industrial X-ray film, the X-ray equipment itself, and densitometric equipment have made possible determining metal thicknesses by radiographic methods with accuracy. The authors developed this method when working with hollow steel propeller blades, but it can be applied to plate, tubing or strip.

With hollow steel propeller blades, the thickness of the metal plate must be held to close tolerances. Previously, the only method of determining 75% of the propeller area was by the destructive method.

A given source of X-radiation of suitable wave length will, under controlled conditions, penetrate the plate with a certain intensity, this intensity being a definite function of the plate thickness involved. If intensity of penetration through plate of known thickness is studied, results can be applied to similar action on plate of unknown thickness.

A set of blocks of known thickness is X-rayed simultaneously with the object whose thickness is unknown. The rest depends on precision of equipment and care by the operator.

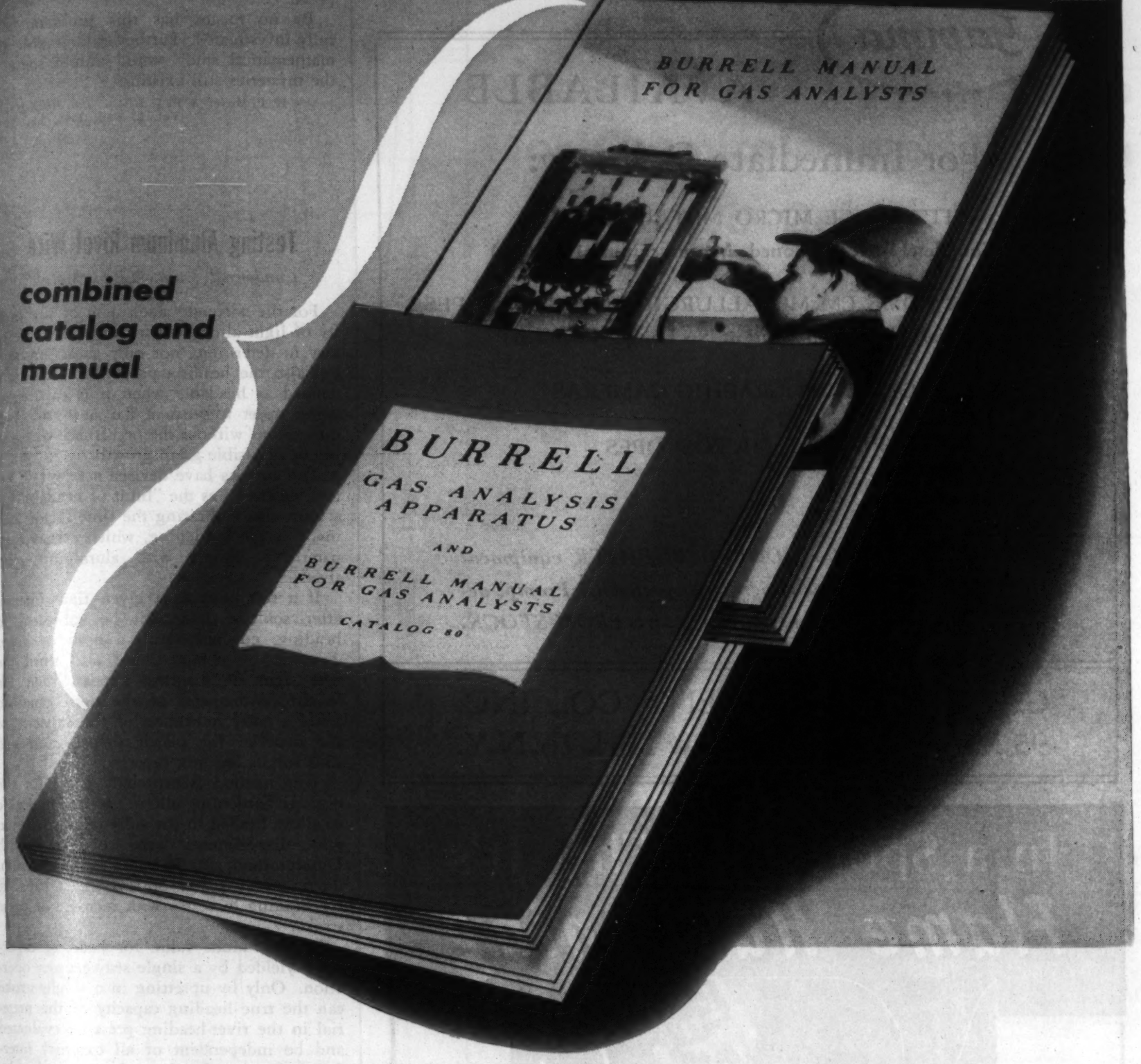
The magnitude of a defect can be roughly estimated by comparing the variations in density between the defect and the stock, with the density variations of the various "steps" of the reference piece. The thicker the plate is, the more the X-rays will be absorbed in this plate and the less the X-ray negative will be affected by the rays passing through the material.

Shots were made with 1-in. squares of the steel used in propeller manufacture (SAE X-4330), ground in 0.020-in. steps over the range of thickness encountered in the propeller design. The range of stock dealt with was 0.060 to 0.300 in.

Techniques used the minimum kilovoltage capable of penetrating the stock to produce the maximum change of film density for a given change in thickness of material, since higher kilovoltages tend to flatten out the contrasts. It is best to use a film having high contrast, thus a commercial fine-grain high contrast, non-screen type.

A 0.015-in. lead backing strip is used immediately behind the film to minimize back scatter, while a 0.005-in. lead filter is used immediately in front of the film to eliminate secondary rays and provide an intensifying effect. To obtain complete uniformity in film emulsions, 7x17 films are cut in two, one piece being used inside the blade while the other is placed under the test blocks.

The holder inside the blade is maintained in position by a rubber bladder blown up to hold the film to the blade contour. The two films are located under



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Because of the prevailing paper shortage, the size of the edition necessarily has been limited. If you have not already requested your copy, we recommend that you write promptly for Catalog 80. Burrell Technical Supply Co., 1936-42 Fifth Ave., Pittsburgh 19, Pa.

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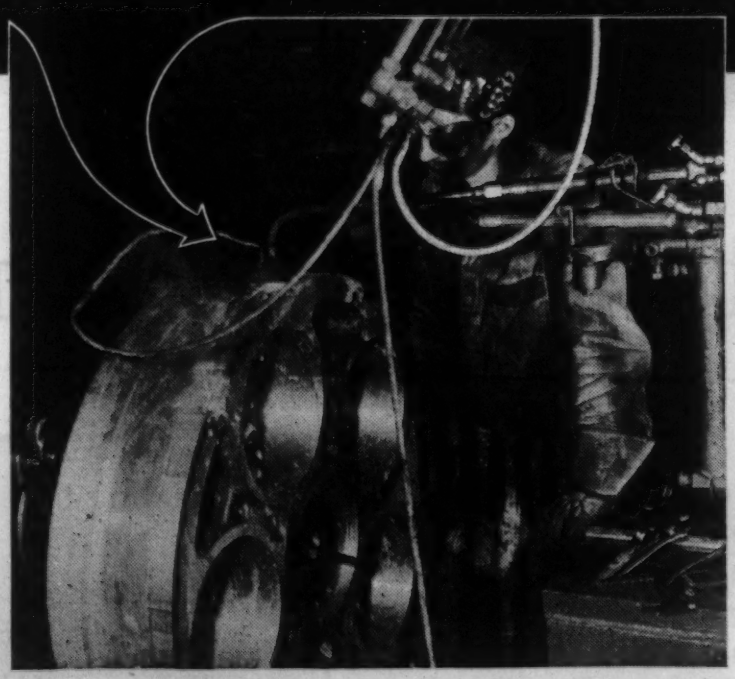

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the X-ray tube and are simultaneously exposed.

By no means has this problem been fully investigated. Further radiographic and mathematical study would unfold some of the mysteries still existing.

—H. P. Moyer & P. L. Kline. *Ind. Radiography*, Vol. 3, Fall, 1944, pp. 34-40.

Testing Aluminum Rivet Wire

Condensed from "Light Metals"

For the adequate assessment of the quality of light alloy wire for rivets it is necessary to determine, not only shear strength, but also the heading properties. A wire is defined as headable when it is capable of being upset to form a flat head of given dimensions without the occurrence of fissuring or of visible grain growth.

The authors have devised a new test system, described as the "limit of headability," a term also embracing the time factor as it involves age hardening, which occurs comparatively rapidly with aluminum alloy rivets.

If a test piece at a given time interval after solution treatment be subjected to heading, not only until a head of given diameter be obtained, but also until the first signs of fissuring appear, then the height or diameter of the head obtained gives a good indication of the capacity of the material for plastic deformation and thus for its heading capacity.

This method is especially good for the non-age-hardening alloys. It is applicable to alloys headed in the fully aged condition also. Experiments were conducted with Duraluminum 681 H in the form of 6 mm. diam. wire. It was observed that capacity for heading increases with increase of press stroke.

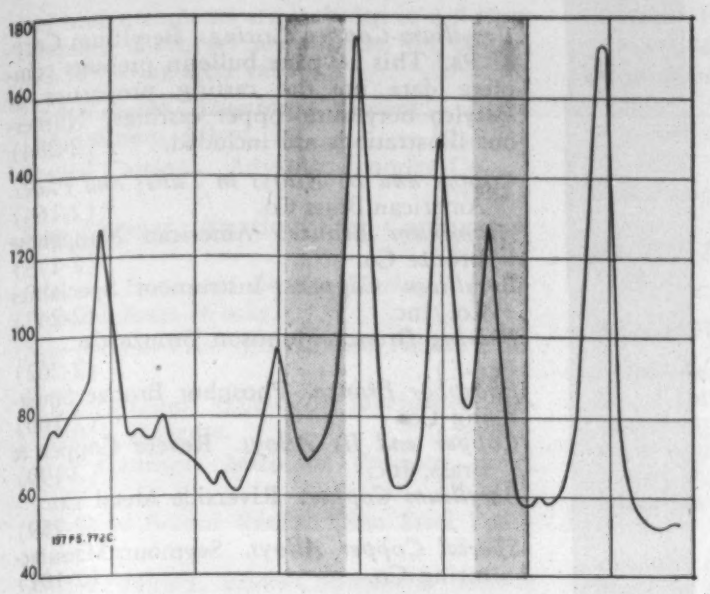
The optimum value for heading capacity is yielded by a single stroke upset operation. Only by upsetting in a single stroke can the true heading capacity of the material in the rivet-heading press be evaluated and be independent of all external interfering factors. In short, it cannot be determined by stepwise deformation.

For this reason, heading capacity is redefined as the smallest height of head that may be given to a test piece in a single stroke without the appearance of fissuring, and for the attainment of a given head diameter. This point is termed "limit of headability."

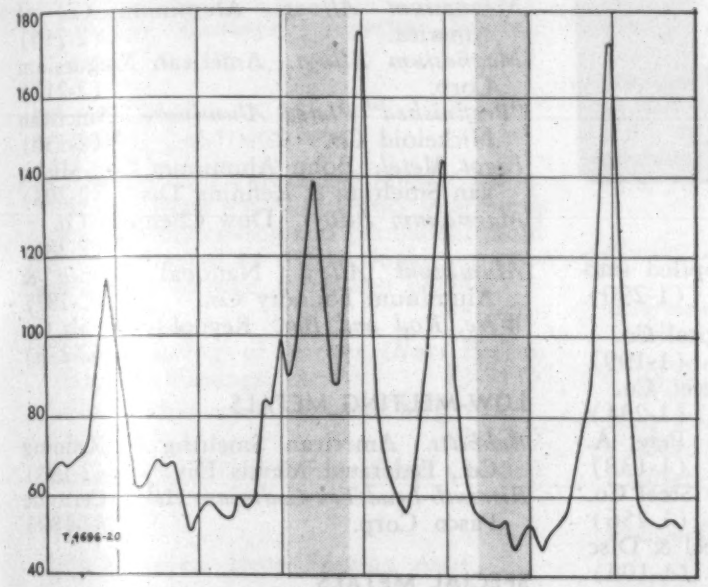
In contrast to previous testing methods, this system gives an immediate evaluation of the heading capacity of the material. Results are based on the height rather than the diameter of the head, as the former is more easily controllable than the latter.

In a typical test one commences with a wire diameter of 6 mm., upset to give a head of 3 mm. diam. If the material successfully withstands this operation, the head is now upset to 2.4 mm. high. Should fissuring appear, a new test is carried out to obtain a head 2.7 mm. high. According to whether or not this test is successful, the limit of headability will be either 2.7 or 3 mm.

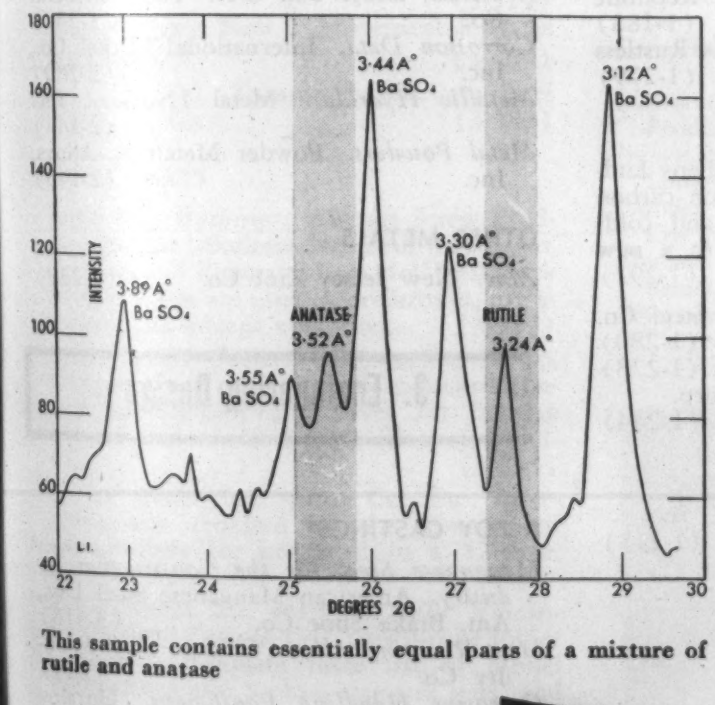
—*Light Metals*, Vol. 7, Dec. 1944, pp. 607-610, 612-614.



Curve shows this sample to be predominantly rutile



Curve shows this sample to be predominantly anatase



This sample contains essentially equal parts of a mixture of rutile and anatase

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Manufacturers' Literature

YOURS FOR THE ASKING

1. Ferrous Metals

ALLOY IRONS

Molybdenum Iron and Steel. Climax Molybdenum Co. (1-76)

ALLOY STEELS

Chemical Limits in Steels. American Steel & Wire Co. (1-191)
Low Alloy Steel. Bethlehem Steel Co. (1-117)
Low Alloy Steels. Great Lakes Steel Corp. (1-171)
High Strength Steel. Inland Steel Co. (1-90)
Molybdenum Cast Steels. Molybdenum Corp. of America. (1-145)
Aircraft Alloy Steels. Joseph T. Ryerson & Son, Inc. (1-210)
Magnet Steels. Simonds Saw & Steel Co. (1-209)

CARBON STEELS

Free-Cutting Bessemer Steels. Bliss & Laughlin, Inc. A 12-page supplement to B & L's 50th anniversary book describes and illustrates free-cutting Bessemer steels—B-1111, B-1112 and B-1113. (1-291)

Aluminized Steel. American Rolling Mill Co. (1-236)
Steel. Youngstown Sheet & Tube Co. (1-227)

HIGH SPEED STEELS

Mo-Max High Speed Steels. Cleveland Twist Drill Co. (1-11)
Tungsten-Molybdenum High Speed Steel. Latrobe Electric Steel Co. (1-175)

STAINLESS STEELS

Stainless Steel. Central Steel & Wire Co. Complete data on the properties and fabrication of stainless steel are concisely presented in a 154-page, indexed handbook. (1-293)

Stainless Steels. Crucible Steel Co. of America. Physical properties, type analysis, heat treatment, electrical properties, etc. of Rezistal stainless steels are all compiled into a compact table. (1-290)

Stainless Steel. Electro Metallurgical Co. (1-199)
Stainless Steels. Firth-Sterling Steel Co. (1-231)
Stainless Steel Identification Data. Peter A. Frasse & Co., Inc. (1-138)
Stainless Clad Steel. Granite City Steel Co. (1-256)
Stainless Clad Steel. Ingersoll Steel & Disc Div., Borg Warner Corp. (1-104)
Stainless Clad Steel. Jessop Steel Co. (1-253)
Fabrication of Stainless Steels. Republic Steel Corp. (1-188)
Heat Treatment of Stainless Steels. Rustless Iron & Steel Corp. (1-279)

TOOL AND DIE STEELS

Drill Rods and Tool Steels. Allegheny Ludlum Steel Corp. Complete data on carbon and high-speed steel drill rods and cold-drawn tool steels are presented in a new catalog. (1-292)

Heat Treating Guide. Carpenter Steel Co. (1-280)
Tool Steels. Copperweld Steel Co. (1-228)
Tool Catalog. Vascoloy-Ramet Corp. (1-244)

IRON AND STEELS—GENERAL

Steel Specialties. A. R. Purdy Co., Inc. (1-213)

2. Non-Ferrous Metals

COPPER AND ITS ALLOYS

Aluminum Bronze Extrusions. Ampco Metal, Inc. This 2-page bulletin describes and illustrates Ampco extruded hollow rod, made of special Ampco metal, for bushings, sleeves, leadscrew nuts, etc. (2-283)

Beryllium-Copper Castings. Beryllium Corp. of Pa. This 16-page bulletin presents complete data on the casting properties of Berylco beryllium-copper castings. Numerous illustrations are included. (2-284)

Copper and Its Alloys in Tubes and Plates. American Brass Co. (2-164)
Aluminum Bronze. American Manganese Bronze Co. (2-173)
Beryllium Copper. Instrument Specialties Co., Inc. (2-247)
Bearing Bronze. Johnson Bronze Co. (2-262)
Phosphor Bronze. Phosphor Bronze Smelting Co. (2-100)
Copper and Its Alloys. Revere Copper & Brass, Inc. (2-199)
Beryllium Copper. Riverside Metal Co. (2-259)
Special Copper Alloys. Seymour Manufacturing Co. (2-101)

LIGHT METALS

Magnesium Alloys. Aluminum Co. of America. (2-215)
Magnesium Alloys. American Magnesium Corp. (2-218)
"Prefinished" Plated Aluminum. American Nickeloid Co. (2-130)
Ingot Metal. Bohn Aluminum Co., Michigan Smelting & Refining Div. (2-204)
Magnesium Alloys. Dow Chemical Co. (2-281)
Aluminum Alloy. National Bronze & Aluminum Foundry Co. (2-187)
Wire, Rod and Bar. Reynolds Metals Co. (2-273)

LOW-MELTING METALS

Babbitts. American Smelting & Refining Co., Federated Metals Div. (2-193)
Bismuth-Lead-Tin-Cadmium Alloy. Cerro de Pasco Corp. (2-189)

SPECIAL METALS

"Foote-Prints"—a house organ on rare metals, alloys and ores. Foote Mineral Co. (2-267)
Corrosion Data. International Nickel Co., Inc. (2-280)
Metallic Hydrides. Metal Hydrides, Inc. (2-144)
Metal Powders. Powder Metals & Alloys, Inc. (2-149)

OTHER METALS

Zinc. New Jersey Zinc Co. (2-229)

3. Engineering Design

ALLOY CASTINGS

Manganese Steel for the Construction Industry. American Manganese Steel Div., Am. Brake Shoe Co. (3-416)
Heat Resisting Alloy. Chicago Steel Foundry Co. (3-19)
Corrosive Handling Equipment. Duraloy Co. (3-183)
Iron Alloy Castings. Duriron Co., Inc. (3-231)
X-Ray Tested Castings. Electro Alloys Co. (3-74)
Heat and Corrosion-Resisting Castings. Sterling Alloys, Inc. (3-513)

CASTINGS—IRON, STEEL, NON-FERROUS, ETC.

Steel Castings. Lebanon Steel Foundry. Specifications, analyses, physical properties

and heat treatments are included in a 4-page reference chart, revised edition, on carbon and low alloy steel castings. (3-539)

Heat Treated Aluminum Castings. Acme Aluminum Alloys, Inc. (3-290)

Special Castings. Advance Foundry Co. (3-381)

Steel Castings. American Steel Castings Co. (3-530)

Data on Brass and Bronze Castings. Hammond Brass Works. (3-194)

Non-Ferrous Castings. Howard Foundry Co. (3-333)

Wear-Resistant Castings. Meehanite Research Institute. (3-487)

Alloy Castings. Michiana Products Corp. (3-512)

Cast Steel Breech Rings. Ohio Steel Foundry Co. (3-447)

Rotary Blowers. Roots-Connersville Blower Corp. (3-229)

Centrifugal Castings. Shenango-Penn Mold Co. (3-250)

Magnesium Castings. Superior Bearing Bronze Co., Inc. (3-532)

DIE CASTINGS, PRECISION CASTINGS, ETC.

Die Casting and Permanent Mold Casting. American Metal Co., Ltd. Two interesting lectures on die casting and permanent mold casting, delivered by Alfred Sugar, are presented in a 48-page, illustrated booklet. (3-542)

Precision Castings of Ferrous Alloys. Bergen Precision Castings, Inc. (3-511)

Castings. Monarch Aluminum Mfg. Co. (3-527)

Die Castings. New Products Corp. (3-468)

FORGINGS

Drop Forgings. Drop Forging Assn. (3-174)

Drop Forgings. Moore Drop Forging Co. (3-519)

Metal Forging. Steel Improvement & Forge Co. (3-409)

Steel Forgings. Transue & Williams Steel Forging Co. (3-383)

METAL PARTS

Spark Plug Bushings. Aircraft Screw Products Co., Inc. Bulletin No. 260, four pages, describes and illustrates how Heli-Coil spark plug bushings are used in production, maintenance and salvage operations. (3-537)

Solder-Backed Contacts. Gibson Electric Co. Complete data on silver solder-backed contacts in Gibsoloy and silver for brazing are presented in a 4-page, illustrated bulletin. (3-545)

Spring Steels. Lee Spring Co., Inc. Interesting data required for the selection of spring steels are presented in a 12-page, illustrated reprint. (3-544)

Steel, Bronze, Etc. Precision Balls. Vulcanite Portland Cement Co. This 8-page folder presents a complete price list of Monel metal, brass and bronze, stainless steel, and chrome alloy steel Universal precision balls. (3-547)

Screw Products. Wisconsin Screw Co. An attractive, 8-page brochure presents a photographic story of the type of work performed and the facilities available at this company's plant. (3-546)

Electrical Contact Metals. Callite Tungsten Corp. (3-338)

Flexible Tubing and Bellows. Chicago Metal Hose Corp. (3-377)

Gears. Fairfield Mfg. Co. (3-514)

Sheet Metal Parts. Kirk & Blum Mfg. Co. (3-238)

Pressure Vessel Fittings. Lenape Hydraulic Pressing & Forging Co. (3-41)

Wear Resistant Precious Metal Parts. Permo, Inc. (3-65)

Bearings. Timken Roller Bearing Co. (3-528)

Ball Reciprocating Bearings. Torrington Co. (3-536)

Eyelets, Ferrules, Etc. Waterbury Companies, Inc. (3-534)

NON-METALLICS

Industrial Rubber Products. B. F. Goodrich Co. Reproductions of 26 advertisements of this company's industrial rubber products, their applications and the many problems solved through the use of rubber are contained in a 26-page, illustrated bulletin. (3-540)

Plastics, Resins, Etc. Hercules Powder Co., Inc. An attractive, 48-page catalog describes a complete line of plastics, resins, explosives, etc., and illustrates the many uses to which they may be applied. (3-541)

Carbon and Graphite Products. National Carbon Co., Inc. A wide variety of carbon, graphite and "Karbate" products for use in the metallurgical, electrical, etc. fields, their applications, physical properties and specifications, are described and illustrated in a 20-page bulletin, No. M-8000-A. (3-538)

Plastic Laminate. Continental Can Co. (3-475)

Alternates for Metals. Continental Diamond Fibre Co. (3-285)

Adaptor Connections. Corning Glass Works. (3-471)

New Plastics. Dow Chemical Co., Plastics Div. (3-369)

Plastics. Durez Plastics & Chemicals, Inc. (3-235)

Plastic Data Book. Formica Insulation Co. (3-210)

Molded Plastics. General Electric Co. (3-283)

Vibration Mounts. Hamilton Kent Mfg. Co. (3-521)

Corrosion-Resistant Equipment. Haveg Corp. (3-271)

Plastic Custom Molding. Imperial Molded Products Corp. (3-389)

Injection Molding Machines for Plastics. Lester-Phoenix, Inc. (3-505)

Plastics. Monsanto Chemical Co., Plastics Div. (3-277)

Molded Plastic Products. Plastic Manufacturers, Inc. (3-430)

Plywood Tubing. Plymold Corp. (3-509)

Plastics. Richardson Co. (3-403)

Cellular Rubber. Sponge Rubber Products Co. (3-533)

Acid-Proof Piping and Fittings. U. S. Stoneware Co. (3-201)

Ceramic Plastics. Westinghouse Electric & Mfg. Co. (3-236)

POWDER METALLURGY

(See also Sec. 2—Special Metals; Sec. 3—Metal Parts; and Sec. 8—Metal Powder Processing)

Powder Metal Bearings and Parts. Chrysler Corp., Amplex Div. (3-473)

Powdered Metal Parts. Keystone Carbon Co. (3-412)

Powder Metallurgy Parts. Moraine Products Div., General Motors Corp. (3-139)

Powder Metallurgy. Powder Metallurgy Corp., Div. General Bronze Co. (3-441)

TUBING

Electric Welded Tubing. Formed Steel Tube Institute. Complete data on the correct fabrication and application of electric welded tubing are presented in an attractive, 32-page, illustrated catalog. Specifications are included. (3-543)

Spun End Tubes. Calumet & Hecla Consolidated Copper Co., Wolverine Tube Div. (3-322)

Piping. Flori Pipe Co. (3-345)

Steel Tubing Bursting Pressure Chart. Globe Steel Tubes Co. (3-493)

Special Tubing. Summerill Tubing Co. (3-337)

History of Piping. Tube Turns, Inc. (3-303)

OTHER METAL FORMS

Weldments. Graver Tank & Mfg. Co., Inc. (3-425)

Magnet Steels. Indiana Steel Products Co. (3-340)

Sheet Wire, Tubing, Etc. D. E. Makepeace Co. (3-529)

Spinning Equipment. Milwaukee Metal Spinning Co. (3-315)

In this Manufacturers' Literature INDEX, new bulletins are given complete reviews, and previously described older bulletins are merely listed in their proper places.

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Titanium, an Alloying Agent. Titanium Alloy Mfg. Co. (4-144)

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Mixer and Check-Relief Valve. Wm. M. Bailey Co. (4-209)
Testing of Foundry Sands, Cores, Etc. Harry W. Dietert Co. (4-221)
Plaster Molding. Castings Patent Corp. (4-219)
Crucible Furnaces. Crucible Manufacturers' Assn. (4-213)
Magnetic Pulleys. Dings Magnetic Separator Co. (4-169)
Foundry Melting Procedures. Foundry Services, Inc. (4-179)
Die Casting Machine. Reed-Prentice Corp. (4-210)

MELTING FURNACES, MACHINES AND PARTS

High Frequency Furnaces. Ajax Electrothermic Corp. (4-60)
Furnaces for Aluminum. Ajax Metal Co. (4-145)
Crucible Furnaces. Campbell-Hausfeld Co. (4-115)
Open-Hearth Furnace. Day & Zimmermann, Inc. (4-224)
Rocking Electric Furnace. Detroit Electric Furnace Div., Kuhlman Electric Co. (4-188)
Melting Furnace Accessories. Fisher Furnace Co. (4-220)
Recuperative Open Hearth Furnaces. Fitch Recuperator Co. (4-101)
Die Casting Machine. H. L. Harvill Mfg. Co. (4-222)
Die Casting Machines. Kux Machine Co. (4-228)
Pot Furnaces. Mahr Mfg. Co. (4-174)
Electric Melting Furnaces. Pittsburgh Lectromelt Furnace Corp. (4-61)
Electric Melting Furnaces, Top Charging. Swindell-Dressler Corp. (4-71)

5. Heating • Heat Treatment

ATMOSPHERES AND GENERATORS

Recarburization. Surface Combustion Div., General Properties Co., Inc. This 8-page, illustrated reprint presents an interesting discussion on skin recovery for decarburized steel surfaces. (5-595)

Gas Carburizers. American Gas Furnace Co. (5-472)
Anhydrous Ammonia. Armour Ammonia Works. (5-435)
Anhydrous Ammonia. Barrett Div., Allied Chemical & Dye Corp. (5-569)
Inert Gas. Davison Chemical Corp. (5-588)
Control of Furnace Atmosphere. C. I. Hayes, Inc. (5-33)
Protective Atmosphere Furnaces. Hevi-Duty Electric Co. (5-449)
Bright Annealing of Metals. Lindberg Steel Treating Co. (5-576)
Atmosphere Furnaces. Lithium Corp. (5-566)
Heat Treating with Ammonia. Pennsylvania Salt Mfg. Co. (5-577)
Drying Air or Gases. Pittsburgh Lectrodryer Corp. (5-500)

AUXILIARIES

Controlled Quenching. Bell & Gossett Co. (5-561)
Butterfly Valves. Bloom Engineering Co. (5-552)
Infra-Red Burners. Burdett Mfg. Co. (5-427)
Pressed Steel Pots. Eclipse Fuel Engineering Co. (5-352)
Sub-Zero Machines for the Metal Industries. Kold-Hold Mfg. Co. (5-349)
Sub-Zero Chilling. Motor Products Corp., Deep-Freeze Div. (5-425)
Quenching Oil Cooling Systems. Trane Co. (5-309)
Wire Belt Conveyors for Furnaces. Wickwire Spencer Steel Co. (5-267)

BATHS AND COMPOUNDS

Case Hardening. American Cyanamid & Chemical Corp. (5-459)
Quenching Oils. Gulf Oil Corp. (5-455)
Carburization Check. Park Chemical Co. (5-351)

BURNERS

Oil and Gas Burners. Peabody Engineering Corp. The mechanical and operating features of both the Type M gas burner and the combined gas and oil burner are presented in a 4-page, illustrated bulletin, No. 902. (5-597)

Controlled Luminous Flame for Billet Heating Furnaces. Morgan Construction Co. (5-147)

ELECTRICAL HARDENING AND HEATING

Electronic Heaters. Federal Electric Co., Inc. Two standard sizes of Fedelco electronic heaters for surface hardening, soldering and brazing are described and illustrated in a six-page folder. Specifications are included. (5-593)

Electronic Power Heating. Radio Corporation of America, Electronic Apparatus Section. An electronic power heating chart for determining operating parameters for various types of dielectric heating problems is presented in a 4-page bulletin. (5-592)

Radio Frequency Generators. Westinghouse Electric & Mfg. Co. Complete data on industrial radio frequency generators for induction and dielectric heating are presented in an 8-page, illustrated bulletin, No. 85-800. (5-594)

Electric Forging Heaters. American Car & Foundry Co. (5-23)
Induction Heat Treating. Central Boiler & Mfg. Co. (5-567)
High Frequency Heating Equipment. Ecco High Frequency Corp. (5-581)
Induction Heating Equipment. Induction Heating Corp. (5-226)
Induction Heating Equipment. Lepel High Frequency Laboratories, Inc. (5-355)
Induction Hardening. Ohio Crankshaft Co. (5-356)

FURNACES

Heat Treating Furnaces. Fabricated Steel & Engineering Co. A complete line of controlled atmosphere heat treating furnaces are profusely illustrated and described in an 8-page bulletin. (5-599)

Electrode Salt Bath Furnaces. A. F. Holden Co. Tables and diagrams in a 4-page bulletin give complete data on a variety of electrode salt bath furnaces for bright hardening, tempering and annealing. (5-598)

Electric Pot Furnaces. American Electric Furnace Co. (5-97)
Furnaces and Furnace Equipment. Amsler-Morton Co., Inc. (5-256)
Blowerless Furnaces. Baker & Co., Inc. (5-574)
Furnaces. Barkling Fuel Engineering Co. (5-580)
Furnace Periodical. Chicago Flexible Shaft Co. (5-291)
Heat Treating Furnaces. Drever Co. (5-258)
Chain Belt Conveyor Furnaces. Electric Furnace Co. (5-166)
Electric Heating Equipment. General Electric Co. (5-284)
Rotary Forging Furnaces. George J. Hagan Co. (5-265)
Electric Furnaces. Harper Electric Furnace Corp. (5-557)
Heat Treating and Laboratory Furnaces. K. H. Huppert. (5-303)
Industrial Gas Furnaces. Johnson Gas Appliance Co. (5-189)
Aluminum and Magnesium Furnaces. Lindberg Engineering Co. (5-421)
Car Hearth Furnaces. R-S Products Corp. (5-392)
Forge Furnaces. W. S. Rockwell Co. (5-558)
Heat Treating Furnaces. Salem Engineering Co. (5-341)
Electric Pot Furnaces. Sentry Co. (5-513)
Electric Furnace. Thermo Electric Mfg. Co. (5-590)
Electric Salt Bath Furnaces. Upton Electric Furnace Div., Commerce Pattern Foundry & Machine Co. (5-595)
Induction Heating Units. Van Norman Co. (5-396)
Car Hearth Heat Treating Furnaces. Vulcan Corp. (5-255)

OVENS

Foundry Ovens. Despatch Oven Co. (5-520)
Heating Equipment. Harold E. Trent Co. (5-578)

PROCESSES

Heat Treating Steel, Aluminum, Etc. Alfred Heller Heat Treating Co. This 32-page catalog describes and illustrates the heat treating of steel, aluminum, brass and copper, including Hellerizing, Chapmanizing, silver finish, etc. (5-596)

Salt Bath Quenching Processes. Ajax Electric Co., Inc. (5-591)
High-Speed Direct Air-Gas Heat. American Gas Assn. (5-589)
Surface Hardening. Chapman Valve Mfg. Co. (5-149)
Wear Phenomena. Nitralloy Corp. (5-541)

6. Refractories • Insulation

Fused Silica and Quartz Products. Amersil Co., Inc. A complete line of fused silica and quartz products, with either sand, glazed or satin surfaces, is presented in a 16-page bulletin. (6-182)

Light-Weight Refractory. A. P. Green Fire Brick Co. A guide to the uses and advantages of Kast-O-Lite, a light-weight, insulating refractory castable, is presented in a profusely illustrated, 20-page bulletin. (6-181)

Lining for Ladles. Ironton Fire Brick Co. A one-page reprint describes and illustrates

Ironton Nojoint, a plastic ramming refractory for lining desulphurizing, mixing and receiving ladles. (6-180)

Insulating Fire Brick. Armstrong Cork Co. (6-179)

Refractory Insulating Concrete. Atlas Lumnite Cement Co. (6-66)

Basic Refractories. Basic Refractories, Inc. (6-166)

Refractory Coating Material. Brickseal Refractory Co. (6-67)

Masonry Saw. Clipper Mfg. Co. (6-82)

Flux Resistant Refractory. Corhart Refractories Co. (6-95)

Steel Plant Cement. Electro Refractories & Alloys Corp. (6-149)

Refractories. Harbison-Walker Refractories Co. (6-173)

Fire Clays. Illinois Clay Products Co. (6-174)

Diatomite. Johns-Manville Corp. (6-134)

Bonding Mortar. M. W. Kellogg Co. (6-170)

High Temperature Cement. Laclede-Christy Clay Products Co. (6-92)

Firebrick. Plibrico Jointless Firebrick Co. (6-129)

Refractories for Aluminum. Charles Taylor Sons Co. (6-133)

Vitreous Silica Pipes, Fittings. Thermal Syndicate, Ltd. (6-50)

Insulating Cement. Universal Zonolite Insulation Co. (6-175)

7. Welding

BRAZING AND SOLDERING

Low-Temperature Welding. Eutectic Welding Alloys, Inc. (7-180)

Silver Brazing Alloy. Handy & Harman. (7-266)

Substitute for Solder. Ideal Commutator Dresser Co. (7-182)

Silver Flux. Scaife Co. (7-224)

Silver Brazing Alloy. Sherman & Co. (7-329)

Hard Soldering Flux. Special Chemicals Corp. (7-351)

Soldering Flux. Wolfe-Kote Co. (7-311)

ELECTRIC ARC WELDING

Welding Electrodes. K. O. Lee Co. A complete list of welding electrodes, including specifications and prices, is presented in a 4-page, illustrated bulletin. (7-357)

Hard Surfacing Electrodes. Rankin Mfg. Co. Complete data on Ranite hard surfacing electrodes for applying a hard, wear-resistant layer of metal to surfaces subject to abrasion are presented in a 12-page bulletin. (7-354)

Stainless Steel Electrodes. Alloy Rods Co. (7-235)

Welding Equipment. American Agile Corp. (7-146)

Stainless Steel Welding. Arcos Corp. (7-103)

Arc Welders, Cranes, Etc. Harnischfeger Corp. (7-333)

Welding High-Nickel Alloys. Hobart Brothers Co. (7-244)

Arc Welding. Lincoln Electric Co. (7-316)

Stainless Electrodes. McKay Co. (7-174)

Arc Welding Electrodes. Metal & Thermit Corp. (7-47)

Stud Welder. Nelson Specialty Welding Equipment Corp. (7-292)

FLAME-PROCESSING

Machine Gas Cutting Tips. Air Reduction Sales Co. This 12-page bulletin profusely illustrates and describes Airco "45" and "45M" high-speed machine gas cutting tips for controlling the expansion of cutting oxygen. Specifications are included. (7-353)

Cutting Torches and Tips. Victor Equipment Co. (7-268)

Hard Surfacing Welding Rod. Wall-Colmonoy Corp. (7-127)

GAS WELDING

Bronze-Welding Alloys. Bridgeport Brass Co. (7-79)

RESISTANCE WELDING

Storage Battery Welding. Progressive Welder Co. Complete data on storage battery welding, applicable to most forms of resistance welding, spot welding, projection welding, etc., are presented in a 12-page, pocket-size booklet. Diagrams are included. (7-356)

Resistance Welding. Sciaky Brothers. This 8-page, illustrated reprint, bulletin No. 204-A, presents an interesting article on three-phase balanced load resistance welding for welding heavy gages, and includes a page illustrating a variety of welders operating on three-phase. (7-355)

Welding Electrodes and Alloys. P. R. Mallory & Co., Inc. (7-342)

Cleaning and Spot Welding. Oakite Products, Inc. (7-237)

SUPPLIES

Arc Welding Electrodes. Allis-Chalmers Mfg. Co. (7-338)

Welding Positioner. Cullen-Friestedt Co. (7-68)

Atomic-Hydrogen Electrode Holder. General Electric Co. (7-153)

Welding Electrodes. Page Steel & Wire Div., Am. Chain & Cable Co. (7-340)

Welding Electrodes. A. O. Smith Corp. (7-261)

Fluxes for Welding, Brazing, Etc. Superior Flux Co. (7-341)

Electrode Holders, Etc. Tweco Products Co. (7-336)

Welding Electrodes. Welding Equipment Supply Co. (7-344)

Ground Clamp. Will-Weld Mfg. Co., Inc. (7-339)

8. Metal-Working

FORMING

Multiple Punches and Spacing Tables. Thomas Machine Mfg. Co. A complete line of improved multiple punches and spacing tables, and their operations, are described and illustrated in a 16-page bulletin, No. 306. (8-619)

Ground Stock, Die Blocks, Etc. Tool Craft Co. A complete line of ground stock, ready-cut die blocks, punch plates and stripper plates is presented in a 4-page, illustrated bulletin. Specifications and prices are included. (8-609)

Hydraulic Press. Watson-Stillman Co. This single sheet describes and illustrates a new, 25-ton, self-contained plain hydraulic press for production of small parts. Specifications are included. (8-610)

Please Use the Coupon on Page 827

Punches and Dies. Wiedemann Machine Co. Diagrams and prices of a variety of high-accuracy punches and dies are presented in a 12-page, illustrated folder. (8-617)

Colloidal Graphite. Acheson Colloids Corp. (8-286)

Pipe Bending Machine. American Pipe Bending Machine Co., Inc. (8-506)

Hydraulic Presses. Anderson Brothers Mfg. Co. (8-279)

Presses. E. W. Bliss Co. (8-254)

Power Presses. Clearing Machine Corp. (8-581)

Pipe and Tube Bending. Copper & Brass Research Assn. (8-476)

Hydraulic Presses. Hydraulic Press Mfg. Co. (8-457)

Double-Flaring Tool. Imperial Brass Mfg. Co. (8-348)

Hydraulic Presses. Lake Erie Engineering Corp. (8-248)

Precision Bender. Leonard Precision Products Co. (8-518)

Steel Plate Fabrication. Marine Fabricators Co. (8-599)

Metal Duplicating Without Dies. O'Neil-Irwin Mfg. Co. (8-561)

Bending Machines. Pines Engineering Co., Inc. (8-251)

Power Presses. Standard Machinery Co. (8-363)

Hole Punching Equipment. Wales-Strippit Corp. (8-548)

FORGING

Hydraulic Presses. A. B. Farquhar Co., Ltd. (8-146)

MACHINING

Grinders. Blanchard Machine Co. This 80-page, pocket-size booklet compactly describes and illustrates the wide application and versatility of these grinders for ferrous metals, many non-ferrous metals, and glass, plastics, minerals, etc. (8-615)

Sump Tank Cleaning Machine. W. R. Carnes Co. A new sump tank cleaning machine, Model No. 20-T, which cleans sump tanks of all sludge, chips, oil and coolant on grinders, lathes, etc., is described and illustrated in a 4-page bulletin, No. M2. Specifications are included. (8-613)

Steel Clamp Fixture. Cincinnati Tool Co. This single sheet describes and illustrates a new steel clamp fixture that has a special slip-proof slide made of heat-treated steel. (8-618)

Broach Sharpeners. Colonial Broach Co. Bulletin No. CS2-44, eight pages, describes and illustrates two types of broach sharpeners for sharpening round and flat broaches, spline and serrated types. Specifications are included. (8-611)

High-Speed Steel Tools. General Aircraft Equipment, Inc., Tool Div. A variety of solid tool bits and tipped tools made with Borcoloy, a high-speed steel incorporating both boron and cobalt, are illustrated and their dimensions in inches tabulated in a 14-page bulletin. (8-616)

Machine Tools. Jones & Lamson Machine Co. A complete line of machine tools, including turret lathes, automatic thread grinders, threading dies, etc., are profusely illustrated and described in an attractive, 20-page bulletin. (8-614)

Abrasive Belts. Minnesota Mining & Mfg. Co. This 12-page, pocket-size pamphlet describes and illustrates 3-M abrasive bench

backstand belts for use on bench backstand idlers. (8-612)

Broaches and Broaching Machines. Lapointe Machine Tool Co. Typical broaching problems and solutions, engineering diagrams and numerous illustrations are included in this attractive, 108-page catalog. Please write request on company letterhead. (8-620)

Clamps and Cylinders. Airop, Inc. (8-584)
Tool Shanks and Cutter Bodies. American Brake Shoe Co., Brake Shoe & Castings Div. (8-361)
Tools for Hardened Steel. Black Drill Co. (8-191)
Oil Filters. Briggs Clarifier Co. (8-538)
Surface Grinder. Builders Iron Foundry. (8-576)
Automatic Control. Bullard-Dunn Div., Bullard Co. (8-605)
Carbide Steel Cutting. Carboloy Co., Inc. (8-392)
Coated Abrasives. Carborundum Co., Globar Div. (8-366)
Metal Cutting Lubrication. Cities Service Oil Co. (8-225)
Mounted Wheels and Points. Cleveland Quarries Co., Sterling Grinding Wheel Div. (8-474)
Oil Filters. Cuno Engineering Corp. (8-108)
Metal Disintegrator. Drafto Corp. (8-568)
Precision Tools. Electrix Corp. (8-601)
Coolant Cutting Compound. Finegan-Campbell Co. (8-558)
Utility Sleeve Tool Driver. J. C. Glenzer Co. (8-577)
Milling Machines. George Gorton Machine Co. (8-545)
Portable Coolant Systems. Gray-Mills Co. (8-364)
Screw Thread Fits. Greenfield Tap & Die Corp. (8-606)
Carbide Tool Grinders. Hammond Machinery Builders. (8-227)
Hydraulic Surface Grinder. Hill Acme Co. (8-570)
Diamond Bonded Wheels. Industrial Abrasives, Inc. (8-380)
Tools. Kennametal, Inc. (8-260)
Grinding Wheels. Larco Diamond Tool Co. (8-444)
Resharpening Checker. Michigan Tool Co. (8-477)
Sawing and Filing. Mid-States Equipment Co. (8-320)
Air-Powered Machines, Etc. Myers Engineering Co. (8-560)
Ordnance Grinding. Norton Co. (8-175)
Manufacturing Service. Oiljak Mfg. Co., Inc. (8-604)
Electric Hand Tool. Precise Products Co. (8-602)
Metal-Cutting Tools. Putnam Tool Co. (8-585)
Metal Cutting Machine. Racine Tool & Machine Co. (8-389)
Shankless Drill. Republic Drill & Tool Co. (8-569)
Torque Tools. Richmont, Inc. (8-579)
Ground Thread Taps. Sossner Tap & Tool Corp. (8-594)
Grinding With Oil. D. A. Stuart Oil Co., Ltd. (8-523)
Precision Grinding Wheels. Universal Wheel & Abrasive Corp. (8-377)
Liquid Honing Process. Vapor Blast Mfg. Co. (8-475)

ROLLING

Solid Steel Shear Knives. Heppenstall Co. (8-224)

METAL POWDER PROCESSING

Cone Blender. Patterson Foundry & Machine Co. (8-493)
Mixers, Agitators, Etc. H. K. Porter Co., Inc. of Pittsburgh, Pa. (8-542)

RIVETING AND FASTENING

Lock Nuts. Columbia Nut & Bolt Co., Inc. (8-567)
Nails, Rivets and Screws. John Hassall, Inc. (8-438)

9. Cleaning • Finishing

CLEANING

Metal Cleaners. American Chemical Paint Co. Technical Service Data Sheet No. 14-6-70-3, three pages, discusses an alkali cleaning process for removing slushing oils from metals, using Ridosol No. 70, an emulsifying agent, and Ridoline No. 30, an alkaline cleaner. (9-508)

Metal Degreasing With Chlorinated Solvents. E. I. duPont de Nemours & Co., Inc., Electrochemicals Dept. Standard practices for degreasing metals or other non-porous materials with chlorinated solvents are discussed in a 10-page, illustrated bulletin. (9-509)

Glass Tanks. Pittsburgh Plate Glass Co. This 4-page bulletin profusely illustrates and describes both transparent glass tanks and metal or wood shells lined with glass for hot acids, electroplating, dyes, etc. (9-515)

Portable Dipping Tanks. Aeroil Burner Co., Inc. (9-366)
Cleaning Machines. Alvey-Ferguson Co. (9-317)
De-Burring Process. De Burr Barrel Co., Inc. (9-499)
Emulsion Cleaning. Enthone Co. (9-350)
Metal Core Brush. Fuller Brush Co., Industrial Div. (9-463)
Metal Cleaning. Magnus Chemical Co. (9-282)
Batch Cleaning. Optimus Equipment Co. (9-483)
Silicate Cleaners. Philadelphia Quartz Co. (9-369)
Surface Peening. W. W. Sly Mfg. Co. (9-422)
Dust Suppressors. Whiting Corp. (9-256)

CHEMICAL TREATMENTS

Rust Preventives, Cutting Oils, Etc. F. E. Anderson Oil Co. Complete data on metalworking oils, rust preventives and metal cleaners are presented in three 6-page, illustrated bulletins incorporated in a single folder. (9-513)

Rust Prevention. E. F. Houghton & Co. Complete data on the causes and prevention of corrosion of metals, including methods of proper cleaning prior to application of these preventives, are presented in a 74-page, illustrated handbook. Rust preventive government specifications are included. (9-510)

Protective Coating. George R. Mowat Co. Griffin's Hytemp, a liquid chrome coating for protection against temperatures up to and in excess of 3500 F., acids, rust, etc., is discussed in a 4-page folder. (9-514)

Oxide Coating on Metals. Alrose Chemical Co. (9-167)
Zinc Finish. Chemical Corp. (9-489)
Black Oxide Finish for Steel. Heatbath Corp. (9-503)
Penetrating Salt Baths. Mitchell-Bradford Chemical Co. (9-454)

ELECTROPLATING

Zinc Stripper. Mac Dermid, Inc. This technical data sheet discusses Metex zinc stripper, an alkaline powder which, when added to water and heated, will strip half a thousandth in. plate in less than 1 min. by a simple immersion process. (9-512)

Selenium Rectifiers. Federal Telephone & Radio Corp. (9-442)
Metal Fluoborates. General Chemical Co. (9-506)
Salvage by Hard Chromium Plating. United Chromium, Inc. (9-180)

METALLIC COATINGS (NON-ELECTROLYTIC)

Abrasion-Resistant Alloy. Wilcox-Rich Div., Eaton Mfg. Co. (9-498)

NON-METALLIC AND ORGANIC COATINGS

Plastic Coatings. American Pipe & Construction Co. (9-324)
Industrial Finish. Ault & Wiborg Corp. (9-505)
Spray Finishing Systems. Binks Mfg. Co. (9-362)
Paints. S. C. Johnson & Son, Inc. (9-270)
Rust Preventive. Nox-Rust Corp. (9-348)
Aluminum Coatings. Quigley Co., Inc. (9-476)
Rust Arresters. Smith Oil & Refining Co., Industrial Oils Div. (9-377)
Spray Finish Machines. Spray Engineering Co. (9-182)
Plastic Coating. Standard Varnish Works. (9-494)

PICKLING

Steam Jet. Youngstown Welding & Engineering Co. The Weldco steam jet for pickling tanks and water rinse tanks is described and illustrated in a 4-page folder. (9-511)

Corrosion Resistant Ceramics. Atlas Mineral Products Co. (9-72)
Chemicals in Metal Industry. Monsanto Chemical Co., Merrimac Div. (9-193)

POLISHING

Cleaning and Buffing Metal Parts. Puritan Mfg. Co. A complete line of buffing compositions and metal cleaners, with emphasis on Purico Wonderbar, a Tripoli buffing composition, is presented in a 24-page, illustrated booklet. (9-507)

Mounted Wheels and Sticks. Carborundum Co., Refractory Div. (9-419)
Polishing Wheel Washer. Divine Brothers Co. (9-417)
Filters. Fostoria Pressed Steel Corp. (9-325)
Deburring and Finishing Metal Parts. Sturgis Products Co. (9-487)

PROTECTIVE PACKING

Plastic Coaters. Youngstown Miller Co. (9-501)

10. Testing • Quality Control

CONTROL INSTRUMENTS

Heating Furnace Control. Askania Regulator Co. The how and why of heating furnace

control is discussed in a new bulletin, No. 122. (10-622)

Remote Mechanical Control. M. L. Bayard & Co. A standardized line of universal and steady shaft assemblies, and bevel gear assembly for remote rotating mechanical control, is discussed in an 8-page, illustrated bulletin, No. A-100. Diagrams and specifications are included. (10-623)

Temperature Control. Burling Instrument Co. A variety of temperature control instruments that use no liquids or gases are described and illustrated in a 6-page folder. An installation diagram and temperature chart are included. (10-620)

Flow Rate Indicator. Fischer & Porter Co. Bulletin No. 92-C, eight pages, describes and illustrates the Rotosight, a flow rate indicator and flow rate alarm that indicates low flows, shows immediately when the flow rate changes, has a wide flow range, and can be read through opaque fluids. (10-624)

Relays. Barber-Colman Co. (10-331)
Air Controllers. Bellows Co. (10-602)
Automatic Control Instruments. Bristol Co. (10-532)
Potentiometer Pyrometer and Accessory Equipment. Brown Instrument Co. (10-259)
Measurement and Control Instruments. Foxboro Co. (10-312)
Portable Pyrometer. Illinois Testing Laboratories, Inc. (10-568)
Tachometers. Jones Motrola Co. (10-591)
Optical Pyrometer. Leeds & Northrup Co. (10-578)
Electric Timers. Paragon Electric Co. (10-605)
Measuring Furnace Gases. Permutit Co. (10-195)
Shielded Pressure Tubes. Revere Co. (10-590)
Thermocouples. Wheelco Instruments Co. (10-337)

HARDNESS TESTING

Sub-Sleeve Dust Protector. Wilson Mechanical Instrument Co., Inc. Bulletin No. SDP-44, two pages, describes and illustrates a sub-sleeve dust protector for covering the elevating screw of a Rockwell hardness tester. (10-619)

Equipment for Hardness Testing. Clark Instrument, Inc. (10-229)
Surface Finish Tester. Taber Instrument Co. (10-153)

INSPECTION DEVICES

Quality Control with Gages. Continental Machines, Inc. Complete data on quality control with DoAll gages and gage instruments are presented in an attractive 140-page illustrated handbook. (10-618)

Optical Testing Equipment. Gamma Instrument Co., Inc. A variety of optical testing equipment, including microscopes, magnifiers, surface projectors, etc., are described and illustrated in a 2-page bulletin. Prices are included. (10-621)

Gages and Dial Indicators. B. C. Ames Co. (10-520)
Thread Gages. Cadillac Gage Co. (10-595)
Illuminated Magnifiers. R. P. Cargille. (10-603)
Identification of Steel. Dravo Corp. (10-271)
Electronic Metal Identifier. Allen B. DuMont Laboratories, Inc. (10-479)
Magnaflux Inspection. Magnaflux Corp. (10-248)
Dynamics Measurement Equipment. Glenn L. Martin Co. (10-601)
Measuring Surface Roughness. Physicists Research Co. (10-616)
Illuminated Magnifiers. E. W. Pike & Co. (10-345)
Gage Blocks. George Scherr Co. (10-458)
Testing Methods. Triplett & Barton, Inc. (10-615)

MECHANICAL TESTING

Strain Gages. Baldwin-Southwark Div. (10-341)
Impact Testing Machine. Tinius Olsen Testing Machine Co. (10-298)
Testing Machines. Riehle Testing Machine Div., Am. Machine & Metals, Inc. (10-593)

METALLOGRAPHIC EQUIPMENT

Optical Instruments. Bausch & Lomb Optical Co. (10-357)
Metallurgical Laboratory Equipment. Buehler, Ltd. (10-199)

RADIOGRAPHY

X-Ray Equipment. North American Philips Co., Inc. Norelco X-ray diffraction equipment for identifying, comparing and analyzing materials is profusely illustrated and described in a 12-page bulletin. (10-617)

X-Ray Films. Ansco. (10-315)
Protection from X-Rays. Bar-Ray Products. (10-374)
Industrial X-Ray Units. General Electric X-Ray Corp. (10-324)
Film Dryer. Pako Corp. (10-588)
Inspection Cabinet. Picker X-Ray Corp. (10-614)

SPECTROGRAPHY

Universal Spectrophotometers. Wilkens-Anderson Co. (10-180)

LABORATORY AIDS

Metallurgical Laboratory Equipment. Precision Scientific Co. A complete line of Precision-Jarrett equipment for the metallurgical laboratory is presented in an 8-page, illustrated catalog, No. 850. (10-625)

Laboratory Equipment. Central Scientific Co. (10-507)
High-Speed Electrolytic Analysis. E. H. Sargent & Co. (10-219)

11. Equipment and Machinery, General

Protected-Type Motor. Crocker-Wheeler Div., Joshua Hendy Iron Works. A new protected-type motor, for both drip-proof and open motor applications, is described and illustrated in a 4-page bulletin. (11-320)

Central Pumping Unit. Farval Corp. A standard automatic central pumping unit, Model DC-25, for handling either oil or grease, is described and illustrated in a 4-page bulletin, No. 40. (11-323)

Slip Clutch and Coupling. Hilliard Corp. A variety of slip clutches and couplings for all types of machinery are described and illustrated in a 4-page bulletin. (11-321)

Please Use the Coupon on Page 827

Paper Dielectric Capacitors. General Electric Co. Bulletin No. GEA-4388, eight pages, presents complete data on high-frequency paper dielectric capacitors for blocking and by-pass applications, and includes a number of diagrams and charts. (11-317)

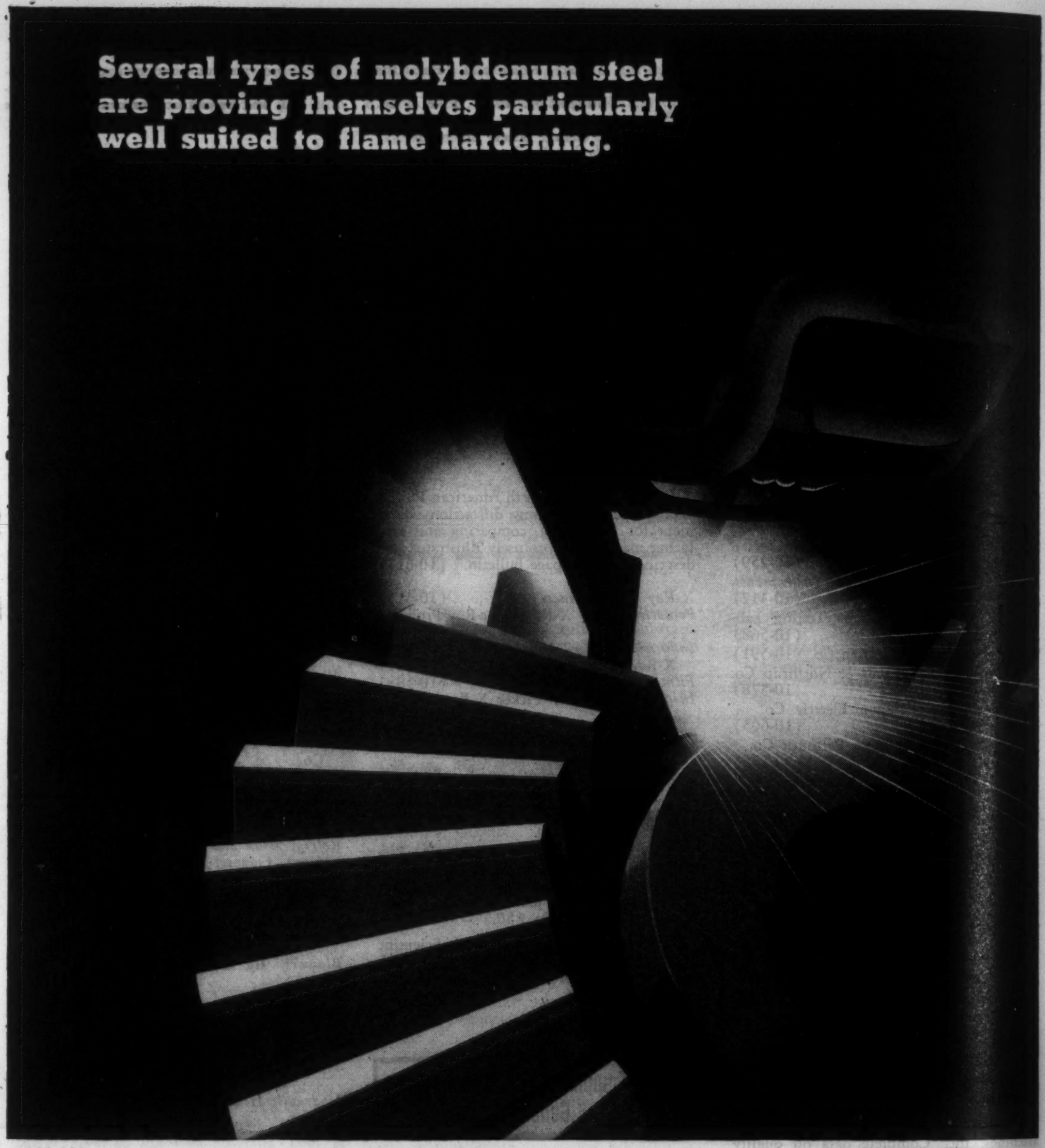
Vibration Control. Korfund Co., Inc. Vibration control for concrete foundations, using steel spring Vibro-Isolators, is discussed in a 4-page, illustrated bulletin. (11-319)

High-Pressure Autoclaves. Struthers-Wells Corp. A complete line of standard and specially-designed high-pressure autoclaves that withstand pressures up to 25,000 lb. per sq. in. is presented in an attractive, 8-page, illustrated bulletin. Specifications are included. (11-322)

Suction and Pressure Line Strainers. J. A. Zurn Mfg. Co. A complete line of suction and pressure line strainers, such as "Y" strainers, angle-type strainers, etc., is presented in bulletin No. 45. (11-318)

Dust Control. American Air Filter Co., Inc. (11-229)
Dust Collectors. American Foundry Equipment Co. (11-206)
Dry Chemical Fire Extinguishers. Ansul Chemical Co. (11-310)
Production Research. Battelle Memorial Inst. (11-296)
Acid-Proof Brick Floors. Belden Brick Co. (11-314)
Fans and Air Conditioning Equipment. Chelsea Fan & Blower Co., Inc. (11-295)
Mounted Wheels for Portable Tools. Chicago Wheel & Mfg. Co. (11-70)
Pumps and Gages. Distillation Products, Inc. (11-309)
Linograph Transfer Paper. Eastman Kodak Co. (11-293)
Induction Generators. Electric Indicator Co. (11-301)
Spreading Machines. Charles E. Francis Co. (11-246)
Refrigeration and Air Conditioning Equipment. General Electric Co. (11-243)
Leather Belting. Graton & Knight Co. (11-308)
Tube Mills. Hardinge Co. (11-175)
Hydraulic Equipment. Hydraulic Machinery, Inc. (11-201)
Blowers. Ilg Electric Ventilating Co. (11-77)
Compressors and Blowers. Ingersoll-Rand Co. (11-315)
Impregnating Castings. Jackson & Church Co. (11-222)
Trucks, Cranes, Etc. Lewis-Shepard Co. (11-312)
Hydraulic High-Lift Truck. Lyon-Raymond Corp. (11-279)
Heat Exchangers. Niagara Blower Co. (11-227)
Dust Preventives. Parsons Engineering Corp. (11-233)
Dust and Fume Control. Peters-Dalton, Inc. (11-242)
Banding and Splicing Method. Punch-Lok Co. (11-307)
Technical Books. Reinhold Publishing Corp. (11-273)
Lubrication for Steam Turbines. Sinclair Refining Co., Inc. (11-197)
Portable Sump Tank. Spencer Turbine Co. (11-219)
Dual Manifold System of Lubrication. Stewart-Warner Corp. (11-249)
High Vacuum Pumps. F. J. Stokes Machine Co. (11-152)
Wire Handles. E. H. Titchener & Co. (11-281)
Air Conditioning Equipment. Westinghouse Electric Elevator Co., Air Conditioning Div. (11-289)

Several types of molybdenum steel are proving themselves particularly well suited to flame hardening.



CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

MOLYBDIC OXIDE, BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"

Climax Molybdenum Company

500 Fifth Avenue • New York City

MOLY

engineering NEWS

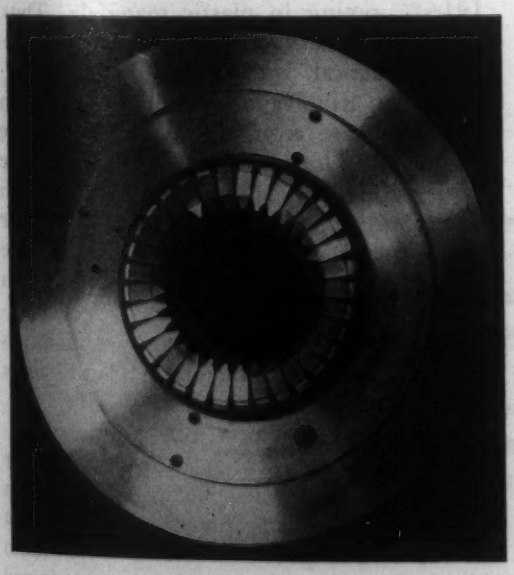
of the metal-working industries

These rather surprising developments are highly interesting as showing the broad extent to which these materials are being used in the war effort. It would be a satisfaction to know in just what applications the various types are used but some of this is probably a military secret. It would be gratifying if the data on these

Radically New Gear Cutter

A revolutionary new method of gear-cutting is announced by *Michigan Tool Co.*, Detroit. Representing the first major advance in equipment and processes for the production of spur and helical gears, splines, etc., since the early part of the century, the machine cuts all gear teeth simultaneously with radially fed form-tool blades having a shear-cutting action.

This "Shear-Speed" can rough and semi-finish cut 60 to 100 or more gears per hr., depending on the job. Cutting time on a gear is well under 1 min.



Michigan Tool Co.'s objective was to bring the speed of gear cutting up to the level set by modern gear-finishing machines. Up to now one gear-shaving machine has been capable of handling the output of a considerable number of shapers and hobbers. With the new "Shear-Speed," production times for rough cutting and finishing can be equalized and predetermined: One "Shear-Speed" and one shaving machine each can be counted on to produce continuously a definite quantity of gears per hr. or day.

It uses for the first time balanced cutting pressure around the gear. Only a simple grinding operation is required to bring dull blades back to correct form.

No particular skill is required for its operation. Gears are merely placed on the work holder. Chucking is part of the automatic machine cycle. The operator merely presses a button to start the machine and when it has completed its cycle it returns to loading position automatically and releases the finished gear for removal and loading of another blank. The design eliminates chance of loose arbors. There are no nuts to tighten.

First of the new "Shear-Speed" sizes to be made available is the 1843—capable of handling gears up to 4 in. in diam. and 2 in. face width. Shoulder gears can easily be handled, since its action is similiar to that of a shaper cutter. Helical gears as well as spur gears can be cut on the new Michigan "Shear-Speed" gear shaper.

The machine incidentally represents the simplest method yet evolved—regardless of speed—of rough and semi-finish cutting of involute splines.

The accompanying photograph represents the interior of the cutter head and the assembly of individual simple form tool blades, each responsible for removing the metal between two adjoining teeth in a gear. This head is for a 50-tooth 4-in. diam. gear.

Blades are simple to sharpen and cutter heads are removable from and replaceable as complete units.

Hard Tool Tips

Black Drill Co., Div. of *Black Industries*, Cleveland, is now supplying a line of tool tips made of "Hardsteel" and designed for brazing into steel shanks. They are made of the same metal used in "Hardsteel" drills for drilling, without previous annealing, of steels hardened by any method.

They are more economical in first cost, are more easily and quickly reground on a standard wheel one or two grades softer than is necessary for high-speed steel, are easy to braze, permit the making of tools that combine a strong toughshank with a cutting edge having the abrasion resisting qualities of the sintered carbides plus the shock resisting qualities of high-speed steel.

They are ideal for machining the harder and tougher steels and the abrasive copper and light metal alloys, either rolled or cast, and they hold their cutting edges over long periods of use at higher cutting speeds and thus save down time.

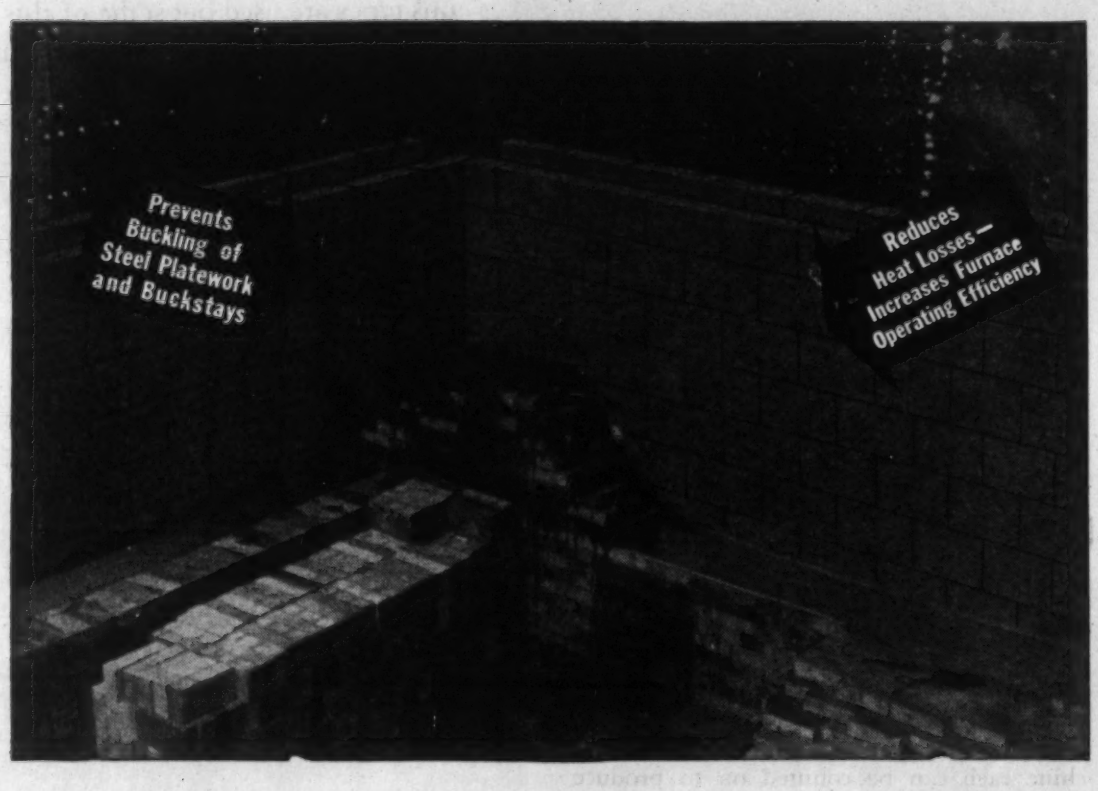
The tool bits are made in all standard sizes, and are available from stock. Special sizes for unusual applications can also be supplied.

This

LIGHTWEIGHT INSULATING BRICK

does "Double Duty"

in Furnace Walls



CONVENIENT 13½ x 9" SIZE—EASY TO HANDLE

REDUCES WALL JOINTS 65%

Other forms of THERM-O-FLAKE INSULATION

Coating — Seals and Insulates all types of furnace walls. Highly plastic, works and spreads easily.

Blocks — Highly efficient insulation where larger size units may be required.

Concrete — Monolithic castable insulation with high insulating value.

Granules — Loose-fill, efficient insulation, weighs only 6 pounds per cubic foot.

Protects furnace steelwork and plating from excessive heat with a strong resilient cushion which absorbs expansion stresses.

KEEPS HEAT INSIDE FURNACE WALLS

Excellent insulation,— a 4½ inch thickness being equivalent in heat flow resistance to more than 29 inches of fire brick.

Find out how quickly THERM-O-FLAKE Brick will pay back their cost in reduced furnace heat losses. For specific data, indicate type of furnace and approx. operating temperatures in writing to:

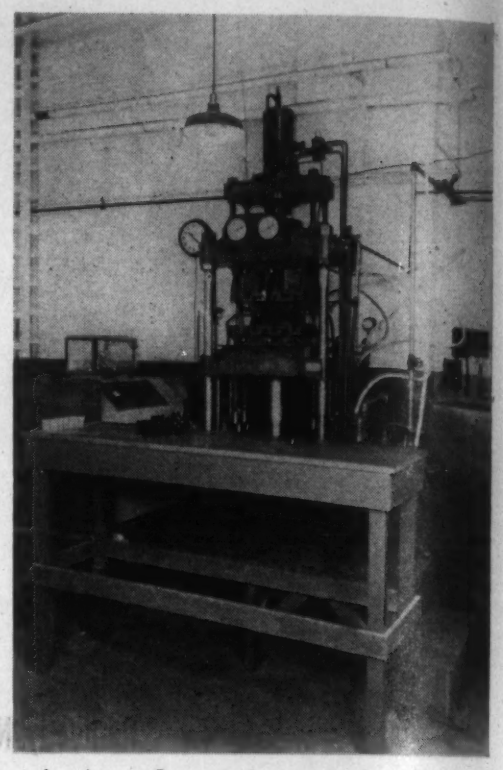
Illinois Clay Products Company
JOLIET, ILLINOIS

Therm-O-flake BRICK

FOR HOT FACE TEMPERATURES UP TO 2000° F.

Press and Electronic Heater for Plastics

A vertical "hyspeed" press that molds plastic items and uses electronic heating of the plastic material to effect sensational economies is claimed by *Baldwin Locomotive Works*, Philadelphia 42. Held secret until now, experiments have been conducted in the *Bryant Electric Co.* Hemco plant, Bridgeport, Conn. on resins, ureas and



melamines. Cooperating were the *Electronic Div., Westinghouse Electric & Mfg. Co.* and the *Plastics Div., Monsanto Chemical Co.*, Springfield, Mass.

The first electronic heating unit and forming press, set up to operate manually, was successful. High frequency heating is a proven success on small parts. Curing time has been reduced from minutes to seconds.

Workmen now turn out 20% more pieces from an experimental 6-cavity mold as were previously done from a standard 24-cavity compression mold, with savings of $6000 in this one experiment plus a 12½% saving in plastic materials. Thus, high-speed thermosetting molding has become practical.

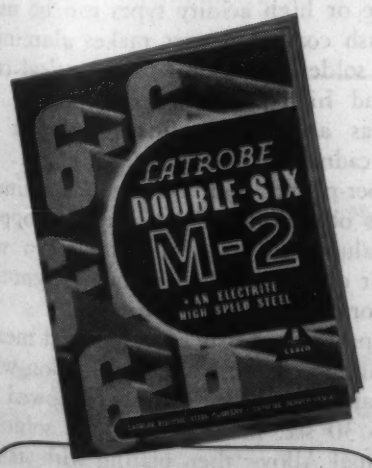
Among its advantages are: Smaller press and mold are required; mold life will be considerably longer because of less pressure on material molded, and materials that can be hobbed more readily can be used for mold construction; molded pieces can be made faster; there is a decided saving in "flash" or waste material and rejects; possible use of substitutes or cheaper materials will save cost; because of no "flash" there are savings in finishing.

At a demonstration one workman operated both the 2-kw. heating unit and the molding press. The plastic, in the form of thick wafers, was placed in the heating device and exposed to short wave radio beams for a few seconds. It was transferred to the press and a plunger forced it down against the mold, remaining under pressure of 6 tons per sq. in. for a few seconds. The product in this case was electric outlet plugs.

Suggested applications are electric in-

TODAY...

LATROBE
DOUBLE-SIX
...meets M-2 specifications



Write for our latest bulletin on Double Six M-2

S-2

Long before Hitler and his hordes over-ran the Low Countries, the war in China had cut off the supply of essential tungsten. That was back in '38, and Latrobe, realizing the urgent need for saving available tungsten, through painstaking research developed a new high speed steel, known as DOUBLE SIX.

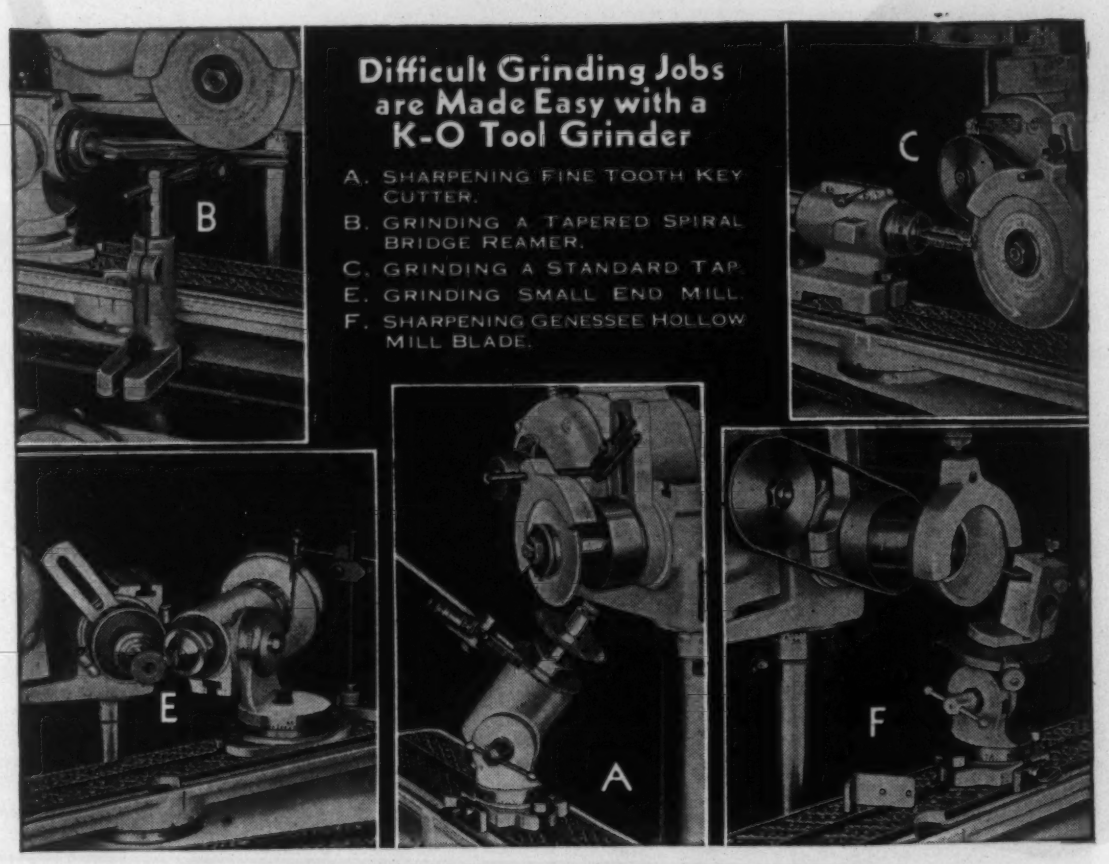
Today, with only minor changes in its original analysis, DOUBLE SIX M-2 meets the automotive industry's specifications for molybdenum-tungsten high speed steels. Born of war-time necessity, Latrobe's DOUBLE SIX M-2 is assured a permanent place in the field of high speed steels, not only for the war emergency but for the peace-time needs to come.

Latrobe ELECTRIC STEEL COMPANY

MAIN OFFICES *and* PLANT •• LATROBE • PENNSYLVANIA

HIGH SPEED STEELS · DIE STEELS · TOOL STEELS · STAINLESS · LATROBE RED ARROW for metal-cutting tools

Cutting Tools Must Be Conditioned for Post War Production Too!



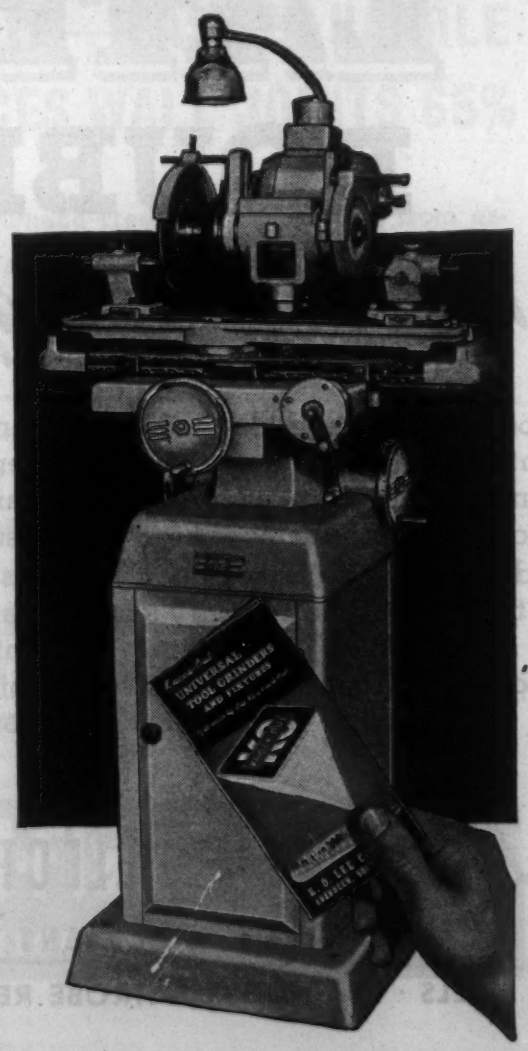
Not All Men and Machines Can Be Released When the War Ends... Some Must Stay on the Job!

When the war broke out, *Knock-Out* Tool Grinders were ready! They've been doing a Titan's job on production work and on tool maintenance throughout the nation and all allied countries. Now as the peace approaches, and thinking men are readying their plants for the tremendous production job which lies ahead, *Knock-Out* Grinders are again ready to accept the challenge!

***Knock-Out* engineers have continually stayed on the alert giving users of K-O Tool Grinders many advantages, making difficult grinding jobs easy.**

Single Speed or Multi Speed Wheel Heads are available. Wheels ranging from 1 to 10 inches can be used. Tools from the smallest to 12 inches in diameter can be ground with speed and accuracy.

When writing for literature ask for Unit No. 34-35.



K.O. LEE CO.
ABERDEEN, SO. DAK.

sulating parts and novelties, which are injection molded from acetates, but may now be made from phenol or urea materials with favorable cost comparison.

The Baldwin presses will be available in capacities from 50 to 300 tons, and can be operated either directly from an accumulation system or separate self-contained motor-driven pump units.

● The application of 4-Way floor plate to the standard Turner transport chassis increases uses of this unit of the Turner system of materials handling, sponsored by *Factory Service Co.*, 4615 N. Twenty-first St., Milwaukee 9. The plate is welded flush with the top of the chassis on the angles of the frame. It is reinforced on the under side by two heavy angles. The "non-skid" feature keeps metal parts from "walking" off easily when the transport is in motion. The embossments provide point contact with hot materials, which allows some air space between them and the steel deck. Warping of the steel deck is thereby eliminated. The transport can be moved in restricted space by the hand Jimmy, power lift truck, crane, tractor or conveyor. With Turner piling stakes, the load may be expanded vertically to any practical height. Steel or wooden bin sections and section trays also interlock one on another on top of this transport, thus making always available bins as high or low as the particular job requires.

Copper Plating on Aluminum

Adherent, uniform copper plating is now possible on aluminum and its alloys by a simple preparatory dip at room temperature, a process sponsored by the *Technical Processes Div., Colonial Alloys Co.*, Philadelphia 29.

The dipping solution may be used in a steel, wood or ceramic container. There are no fumes, hence no required venting. The solution has a long life, is stable and not sensitive to drag-out, normal contamination or dilution. Any copper electrolyte except sulphate or high acidity types can be used.

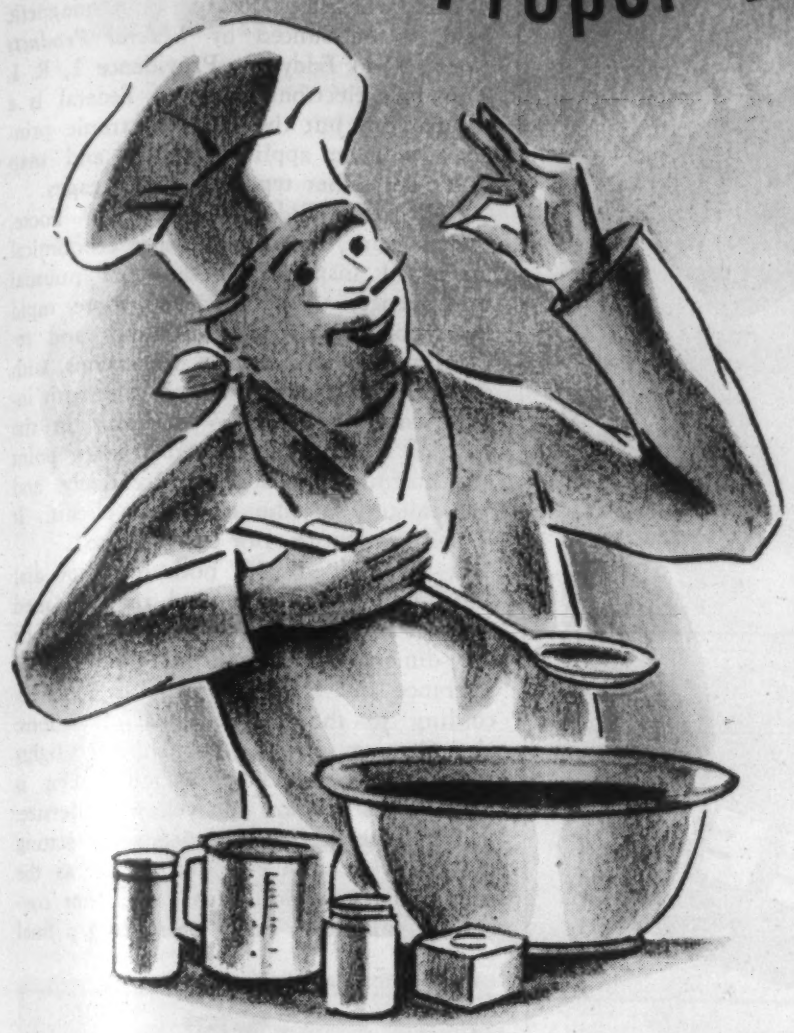
A flash coat of copper makes aluminum easy to solder and useful for electrical contacts and high frequency conductance. It serves as a base for further plating by nickel, cadmium, chromium, zinc, etc.

Copper-plated and polished, aluminum loses its objectionable dull finish. Copper-plated aluminum can build up worn surfaces. It can be finished in many light-fast colors for decorative, etc. purposes.

The process consists of a specified means of aluminum cleaning and preparation with some standard alkaline cleaner, followed by a 10 to 30 sec. immersion in the solution of Colonial Alloys; then plating with standard electrolytes such as cyanide or rochelle copper.

Acid passivator is sold by Colonial under agreement with the user, which also applies to the last alkaline immersion bath prior to actual plating.

Proper Blending Pays



Plastics AND DIE CASTINGS for Your New Products

Food in the raw becomes a savory dish only in the hands of an expert. Such essential skill stems from ability to combine the right ingredients in the right amounts—and so combined are the energy and production skills and materials of New Products Corporation and Modern Plastics Corporation.

Today this coordinated experience can help you to utilize effectively a combination of high pressure die cast and molded plastic parts in your product. Why not write either of these companies today? Perhaps they can give you scientific and profitable assistance in solving your problems.

Two Independent Organizations Dedicated to Your Product Development

•NEW PRODUCTS ★ MODERN PLASTICS•

CORPORATION CORPORATION

BENTON HARBOR, MICHIGAN, U.S.A.

R-S FURNACE DESIGN

R-S

QUALITY PRODUCTS SINCE 1908

SAVES TONS OF STEEL

The specifications for three large Heat Treating Furnaces called for a considerable amount of steel. R-S Engineers altered the design of the furnaces which resulted in a saving of 15 tons of critical materials and a cash saving to the purchaser without any reduction in operating efficiency. Furthermore, the furnaces were placed in operation on essential war material at least six weeks ahead of the specified operating time.

Another R-S project demanded a unique design and novel material handling arrangement to heat treat steel castings for American tanks. It involved precise temperature control, as well as timing the speed of handling to coordinate all cycles of an intricate heat treating process. The desired ballistic and metallurgical properties were achieved with a minimum of manpower. Many steel foundry men consider this one of the most outstanding installations of its kind in the country. It has produced thousands of tons of vital war material on schedule.

You can depend on R-S Engineers to design a furnace skillfully so that the desired physical properties of the finished work will meet all requirements; to save critical materials and manpower wherever possible; to make delivery promptly.

If you have an industrial heat treating problem, write on your company letterhead for helpful suggestions.

R-S Furnaces of Distinction

FURNACE DIVISION
R-S PRODUCTS CORPORATION

4522 Germantown Avenue • Philadelphia 44, Pa.

BUY WAR BONDS

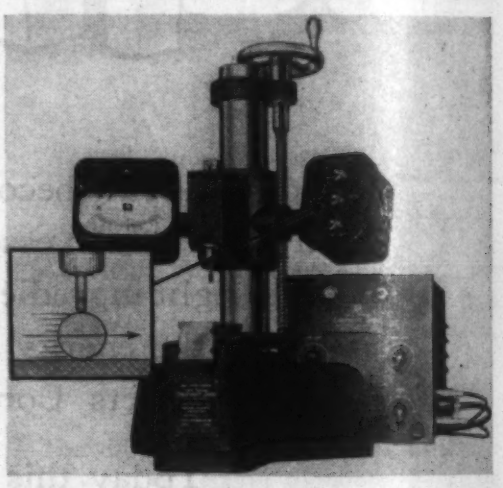
Electronic Type of Gage

An electronic type of gage that does not depend on the "make and break" electric circuit, wheatstone bridge or a magnetic field, is announced by *Federal Products Corp.*, 1144 Eddy St., Providence 1, R. I. This first electronic gage of Federal is a comparator, but the same electronic principle will be applied to hole and snap gages and other types of special gages.

Called the Federal Model 130 Foote, Pierson gage, it affords a more economical means of inspection because of unusual convenience, adaptability and more rapid inspection with greater accuracy and reliability. One can inspect dimensions, with small tolerance limits, at low cost with inexperienced operators. Variations in the position of the mechanical contact point are magnified sensitively, accurately and conveniently by the electronic circuit. It is neither delicate, nor easily abused.

It is provided with both indicator dial and limit lights. The dial may be used when it is desired to determine how much the dimension varies from the specified tolerance and for selecting workpieces according to their dimensional variations; also when setting the gage. The limit lights provide very rapid inspection—green is okay, red is oversize and yellow, undersize.

Only one mechanical means for setting to within ± 0.003 in. is needed as the wide range electrical zero adjustment covers the full scale, easily permitting a final

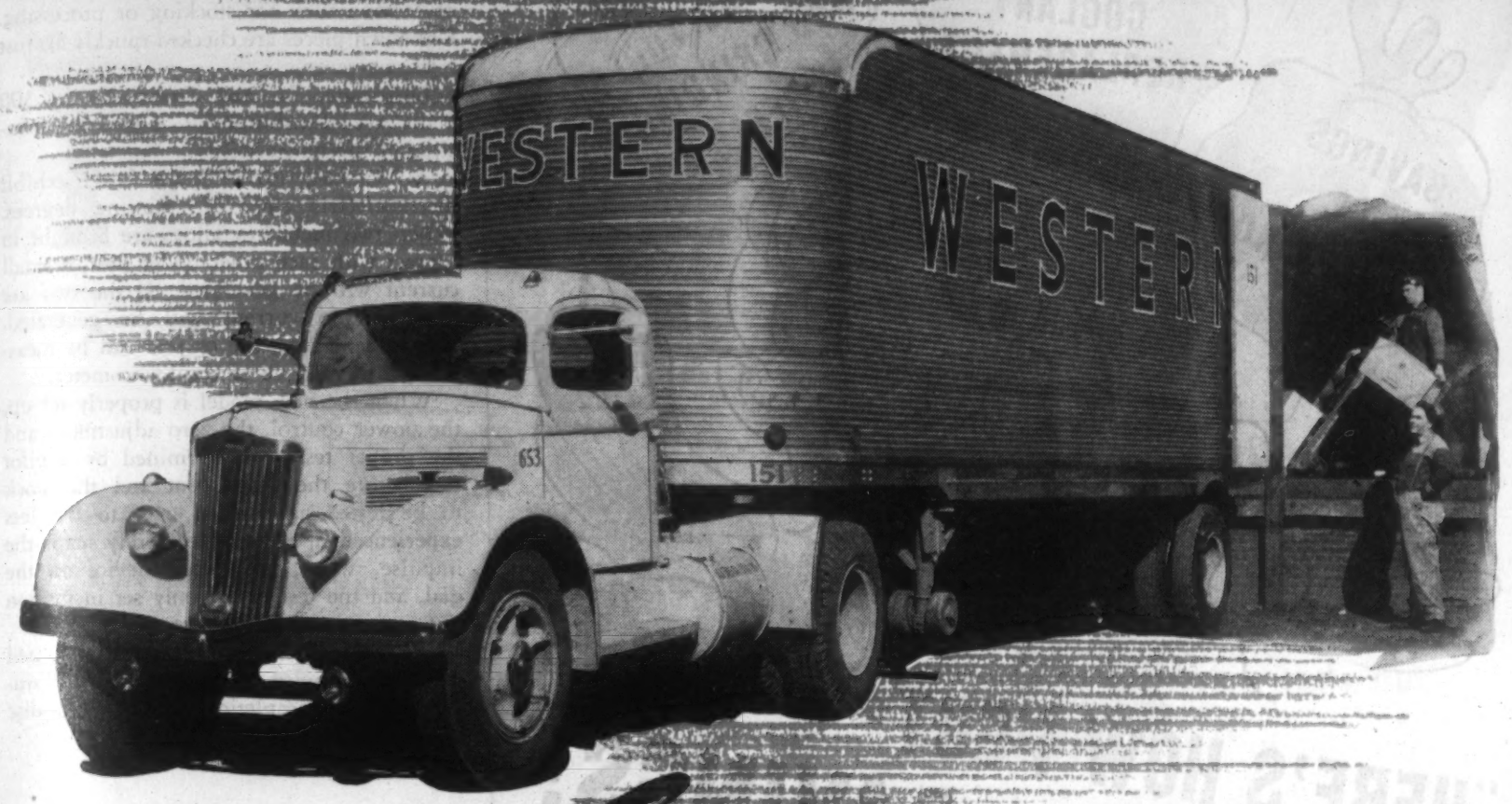


zero setting even on the most sensitive scale. The indicator dial is provided with two scales—lower graduated 3-0-3 and upper, 1-0-1. The smallest division of each scale is equal to either 0.0001 or 0.00001 in.

Any one of four magnifications may be selected by a 4-position selector switch. The contact pressure can be adjusted from 1½ oz. to 16 oz. Voltage fluctuations of ± 10 volts in the power supply affect the accuracy by under 1%.

● Plans for the construction of an 18,000-ton die forging press, largest installed in this country, are announced by the *War Production Board*. The largest previous press for light metal forgings was one of 10,000-ton capacity. Germans have made magnesium forgings up to 5 or 6 ft. long, used for engine mounts in aircraft, but the 18,000-ton press will allow for even larger metal parts.

MORE PAY LOAD ★ MORE PROFIT



with Republic *Enduro* Stainless Steel

● Most people think of Republic ENDURO Stainless Steel as a bright, shiny material that resists rust and corrosion.

They're correct. But ENDURO is more than that. It is a tough, high strength material—so strong that it may be safely used in thinner sections to reduce dead weight in all types of transportation equipment.

And every pound you can cut from the dead weight of your equipment means just another potential pound of pay load to increase trip revenue. It also means less wear and tear on tires and moving parts—lower fuel consumption.

Then ENDURO brings another advantage to transportation equipment. Because it is resistant to rust, it does not require painting, and repainting, for protective purposes. The only painting you'll put on an ENDURO body is your name and whatever other lettering is necessary.

If you've never experienced the profit advantage of ENDURO equipment, now is the time to talk to your body manufacturer about equipment for tomorrow. Write us and we'll be glad to send you the names of body builders and descriptive literature on ENDURO.

REPUBLIC STEEL CORPORATION

Alloy Steel Division • Massillon, Ohio

GENERAL OFFICES • CLEVELAND 1, OHIO

Export Department: Chrysler Building, New York 17, New York

Republic

REPUBLIC STEEL — PRODUCTION FOR VICTORY

ENDURO STAINLESS STEEL

Reg. U. S. Pat. Off.

Other Republic Products include Carbon, Alloy and "Quality" Steels—Pipe, Sheets, Strip, Plates, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

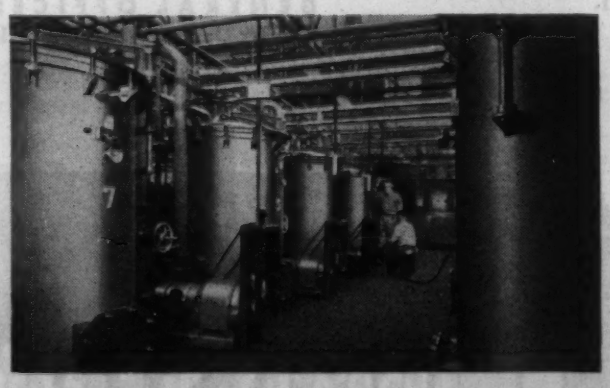
"HERE'S HOW I GOT ALL KINDS OF SAVINGS!"

Developed as the result of wartime need for precision finishing on a production basis, Hoffman coolant filtration is amazing and delighting users with unexpectedly big savings in maintenance, in coolant replacement, in longer life for machines, cutting tools and grinding wheels, and in fewer rejects.

ARMY E NAVY

POUGHKEEPSIE PLANT

At right: Hoffman centralized installation for filtering coolant from a large number of machines. Other Hoffman models are available for individual machine tools.



SEND FOR LITERATURE

U. S. HOFFMAN MACHINERY CORPORATION
223 Lamson St., Syracuse, N. Y.
COOLANT FILTERS • FILTRATION ENGINEERING SERVICE

Electronic Identometer

A new model of Identometer features improvement through an electronic timing control that eliminates the human factor in timing tests for positive identification of ferrous metals and speeds up the work. The function of the machine is to identify rolled or ferrous alloy for stocking or processing. Unknown pieces are checked quickly against a known sample.

Distributed by the *Dravo Corp.*, 300 Penn Ave., Pittsburgh 22, it uses the principle of thermoelectricity.

All metals, except pure lead, exhibit thermoelectric effects to varying degrees. When two metals or alloys are brought in contact with each other under heat, a small current will be generated. If the two are identical, no current will be generated. Where generated, the current can be measured, the principle of the Identometer.

When the new model is properly set up, the power control, the zero adjustment and the proper test are determined by a pilot test before the instrument and the stock to be tested are turned over to the less experienced operator. He merely snaps the impulse switch, the lowest device on the dial, and the test is not only set in motion but maintained for the correct interval.

The entire reading scale is illuminated when the impulse switch is moved, remaining until test completion. Then a small disc of light signals completion.

● A new snap-fast face shield makes possible visor replacement in 15 sec. Perforations in the visor fit snugly over small lugs, spring clamps holding it firmly in place. A turn of the fingers snaps out the old visor. It is good for flash, butt and spot welding, and heavy grinding, etc. It fits snugly against the chest to prevent entrance of flying particles. The form-fitting headgear, with leather sweatbands, makes for comfort. The *Chicago Eye Shield Co.*, 2300 Warren Blvd., Chicago 12, makes four styles, with two visor thicknesses.

Three-Metal Plating Process

A new plating process using copper, tin and zinc is providing a tough, non-magnetic coating for the delicate parts of many instruments that check the performance of fighting machines, it is revealed at the *Westinghouse Meter Div.*, Newark, N. J., a process made available through *Hanson-Van Winkle-Munning Co.*, Matawan, N. J.

The process steps up resistance of electrical instruments to corrosion. Instruments so coated are particularly corrosion-resistant in the tropics. They stand 200 hr. of continuous salt spray. When coating with nickel at least five ten-thousandths of an inch of metal is needed—two and a half times the thickness needed when this bright alloy coating is used. This thinness improves electrical conductivity.

Electrical performance is improved by the non-magnetic coating, hence affording more accurate dial readings on recording

A High Strength Aluminum Alloy
That Does Not Require Heat Treatment

Frontier Alloy "40-E"

and Offers

Shock Resistance — Tests have proved its exceptional ability to withstand explosive shock and standard impact shock.

Corrosion Resistance — Excellent, not only in standard corrosion tests but also under stress.

High Yield Strength — A dominant factor where distortion or misalignment of parts would make the assembly inoperable.

Machineability — Far superior to the usual sand cast aluminum alloys and machined parts have a high lustre.

Pressure Tightness — The fine grain of the alloy enables it to withstand high pressures.

Specifications . . . Army-Navy Aeronautical Spec. AN-A-17; U. S. Navy Spec. 46A-1 (INT), Class 1; A. S. T. M. Spec. ZG-41, alloy O.

Typical Physical Properties . . . tensile strength, 35,000 psi.; yield strength, 25,000 psi.; elongation, 5% in 2".

ENGINEERING Data on Request

Handy Alloy Data Book, containing metallurgical and engineering data, now available. Write for your free copy, stating your name, title and address.

● Foundries from coast to coast are now "40-E" licensees. Increased demand for "40-E" castings has required an increased production of this new alloy and necessitates the licensing of additional foundries. Your request for complete licensing data will receive prompt attention.

FRONTIER BRONZE CORPORATION
P. O. Box 618
Niagara Falls, New York

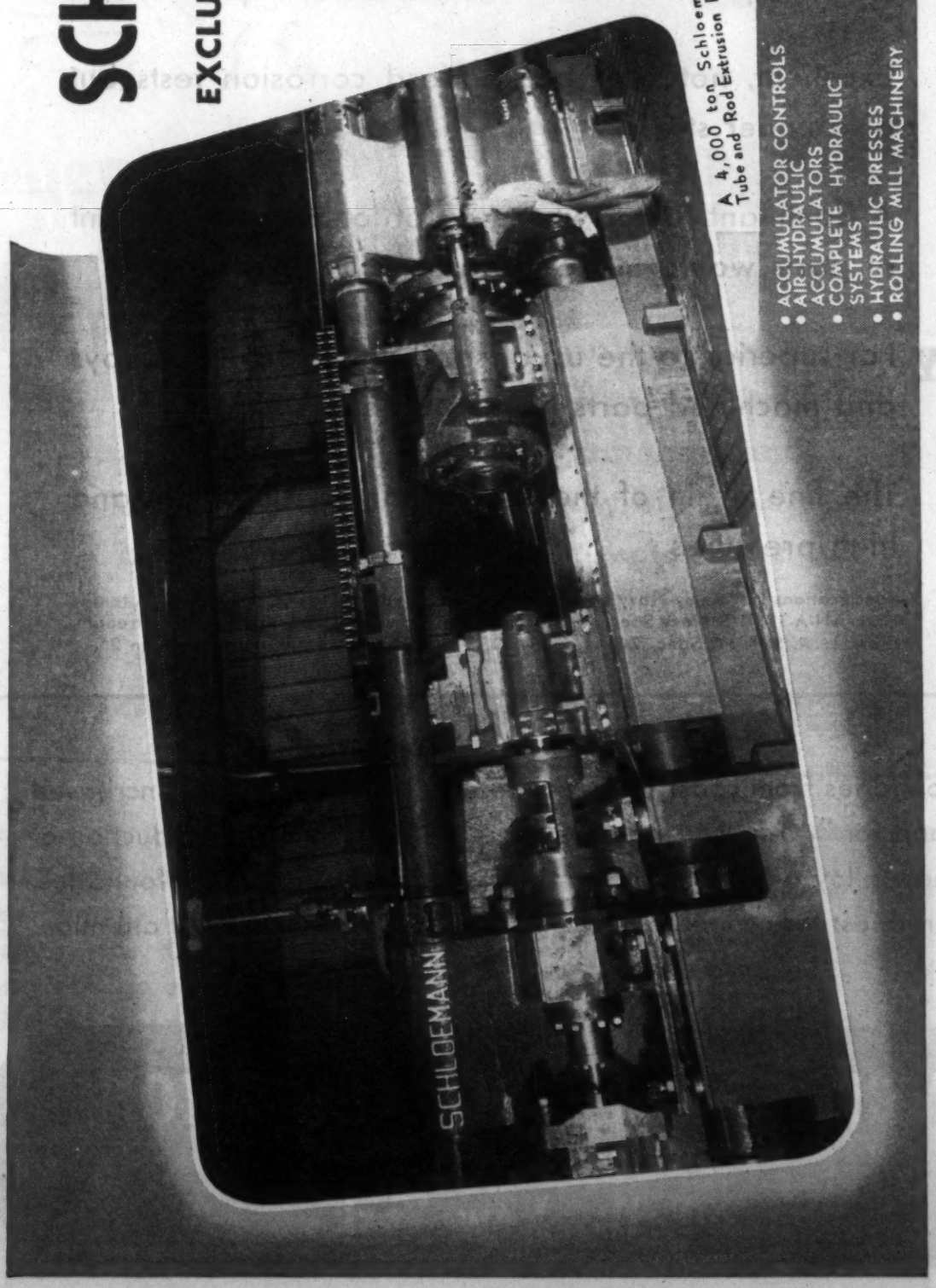
SCHLOEMANN PRESSES

EXCLUSIVE DESIGN FOR *Superior* EXTRUDING

Recognized throughout the non-ferrous industry as economical machine tools, Schloemann Extrusion Presses incorporate exclusive design features permitting superior diversified extrusions.

The patented method of supporting the platen and container holder in the centerline of the container is an example of exclusive design. It permits expansion and contraction of those parts in all directions without losing alignment with the centerline of that part of the machine that carries the press stem and remains cold.

Our engineering staff is available to assist you with your extrusion problems, without obligation.



SCHLOEMANN
ENGINEERING CORPORATION
2100 EMPIRE BLDG., PITTSBURGH 22, PENNA.

instruments. The new plate has saved precious gold, which is in some ways inferior because of poor corrosion protective properties and softness, which causes easy abrasion.

Bright alloy plate can be deposited electrolytically on virtually any size or shape of metal object and as thin as one one-hundred-thousandth of an inch. The key to the success of the process is an "addition agent," a chemical salt that increases "throwing power," or ability to penetrate into deep, narrow crevices. Again, the agent reduces the size of the crystals of deposited metal so that they lie "flat," instead of in a jumbled mass, resulting in a bright, shiny surface.

Interesting post-war applications may be refrigerator trays, typewriters and other office machines, delicate measuring instruments and gages, draftsmen's tools and works of clocks.

In the accompanying photograph copper bands for vital war instruments are being withdrawn from the plating bath by George W. Jernstedt, Westinghouse research engineer, inventor of the process.

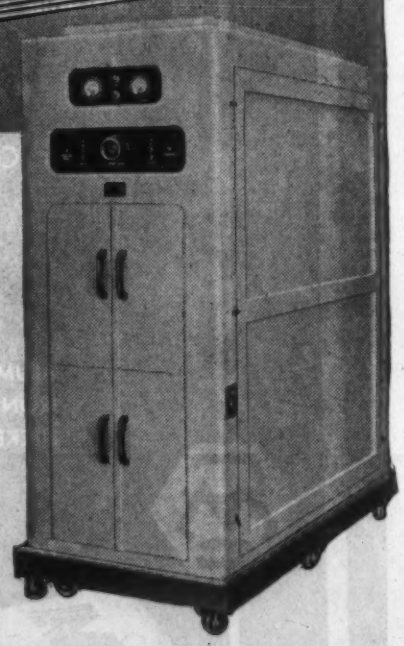
Deepest Salt Bath Furnaces

Two Ajax-Hultgren electric salt bath furnaces, recently installed in a large midwestern plant for isothermal heat treatment of special ordnance parts, represent the deepest salt baths constructed to date. These furnaces have a salt depth of 7 ft. Both furnaces, austenizing and quenching, are internally heated by closely spaced electrodes —an exclusive Ajax design principle.

Large baths of this kind are made practical only by internal heating, since localized overheating and premature pot failures are eliminated. Electromagnetic forces are developed by close electrode spacing, creating a vigorous stirring action which results in immediate circulation of heat and holds temperature variations throughout the bath to a maximum of 5 deg.

Data on the revolutionary isothermal heat treating process is available from *Ajax Electric Co., Inc.*, Frankford Ave. at Delaware Ave., Philadelphia 23, Pa.

MAILED FREE on request!



At last! Industries' *new* and *revolutionary heating process* explained in a language understandable to everyone. In fifteen minutes reading time, you will gain a complete basic knowledge of Electronic Heating. This important handbook discusses all the essential facts you have to know in considering the application of Electronic Heating to your own manufacturing methods.

It contains a brief record of the historical background and development of the process — explains the principle of its operation — describes the two chief methods and fields of application and lists many proved present-day uses.

Let us send you a complimentary copy at once. Fill in the coupon or write on your company letterhead.

Manufacturers of Vacuum Tube and Spark Gap Converters since 1921

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Please rush my complimentary copy of *The ABC of Electronic Heating* today to:

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NEW

information about

CERIUM

From world wide sources, we have compiled a selected list of literature and patent references regarding the use of CERIUM* with Aluminum and Magnesium. Similar references are in preparation covering the fields of

Degasifying • Grain Refinement
Deoxidizing • Corrosion Resistance
Heat Resistance • Getters • Catalysis

These references cover widespread industrial applications of major importance to metallurgists, production engineers, manufacturing executives—now and post war.

Make sure of receiving this — and future — important data by registering your name with us.

Start your CERIUM file by writing us today.

***CERIUM STANDARD ALLOY**

Containing 45-50% Cerium — Balance principally rare earth metals.

Also available

CERIUM MASTER ALLOYS

with

ALUMINUM • CARBON • COPPER • GOLD
IRON • LEAD • MAGNESIUM • MANGANESE
NICKEL • SILICON • SILVER • TIN

OTHERS ON REQUEST

The Source for Facts about Cerium

CERIUM METALS
CORPORATION
522 FIFTH AVENUE
NEW YORK 18, N. Y.

● Damage to carbide tipped tools in transit, stockroom or toolroom bin is eliminated by a strong plastic coating to each tool tip at the plant of *Wendt-Sonis Co.*, Hannibal, Mo. It is applied immediately after final inspection at the plant. It is air and moisture proof, and does not leave any gummy residue on working surfaces.

Dry Drawing and Annealing Compound

A dry drawing and annealing compound, applied as a waxy, aqueous solution, is being used with marked success in the deep drawing of brass and steel. It is applied in varying strengths to give a very nearly imperceptible wax coating, hardly visible but with a slightly waxy feel to the surface.

Called No. 268 by its maker, the *Plasteel Corp.*, 3900 W. Jefferson Ave., Ecorse 18, Mich., it is applied in either a drum- or spray-type mechanical washing machine at 175 to 185 F. Pieces are treated immediately after the pickle line or wash.

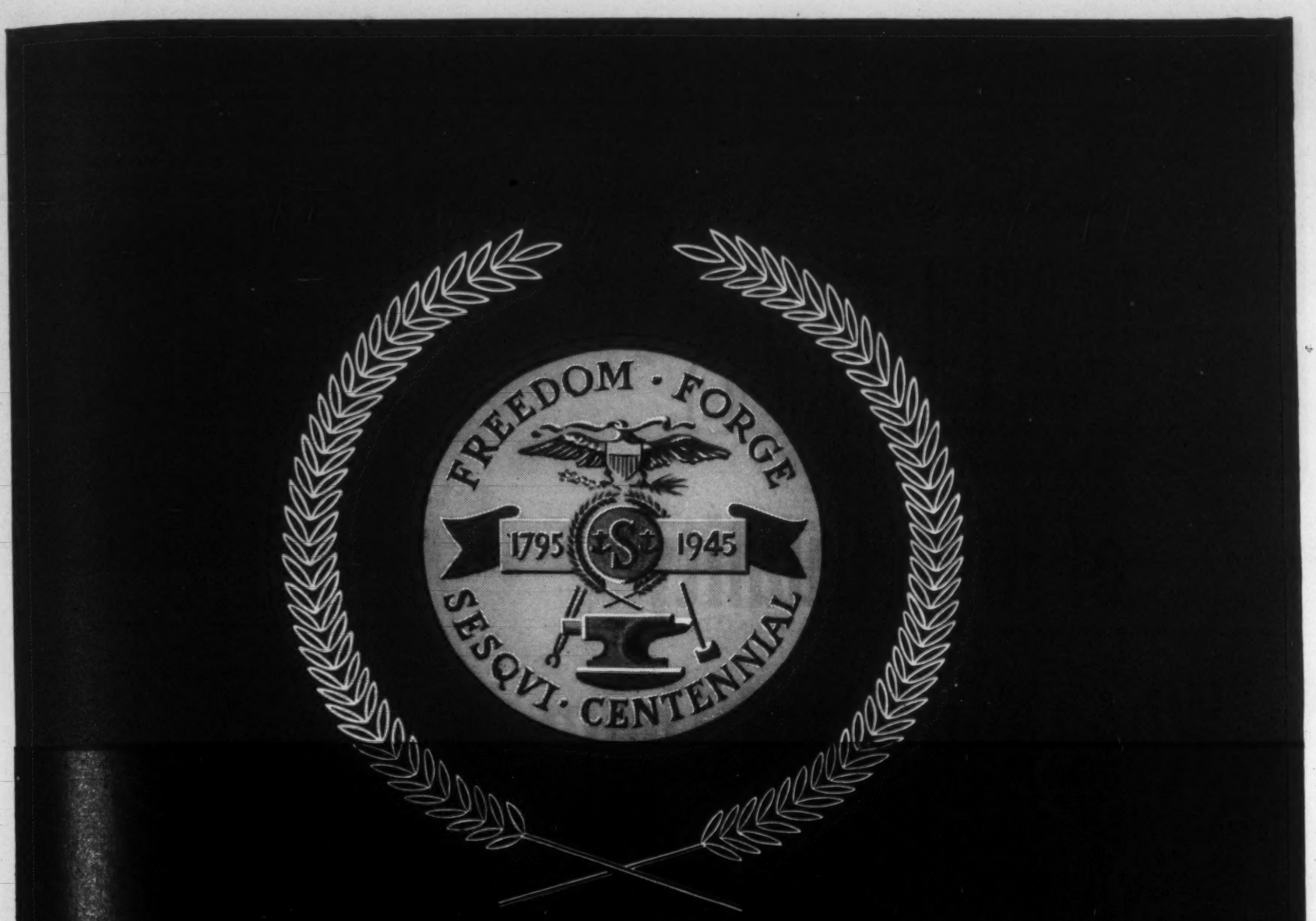
This coating prevents formation of hard mill scale during anneal, but does produce a thin, porous, protective scale, easily removed in subsequent pickling. It applies equally well to minutely imbedded hard scale on the piece before drawing.

Pieces can be drawn without coolant or added lubricant. In case of two draws in sequence, it is unnecessary to re-apply the compound before the second draw, though interposition of cleaning, annealing or pickling between draws would call for re-applying the compound.

Where No. 268 is used to replace conventional coolants it shows up favorably in six respects: It greatly increases die life; it reduces number of operations (in one case from 48 to 37); it greatly reduces scrap; it makes pickling more effective; there is no corrosion problem while the wax is on

the part; it is an entirely clean operation from standpoint of operators, plant and equipment.

The accompanying photograph shows the immaculate condition of both operator and press.



celebrates its Sesqui-Centennial

Midway in Washington's second term, Freedom Forge craftsmen began the production of essential metal parts for the infant industries of the infant republic . . . and forged the first link in a chain of service that extends unbroken up to today.

Of the American inventions that are commonplace in this generation, only the lightning rod, the submarine torpedo, the steamboat and the cotton gin had already been developed. The first railroad was still 35 years in the future, and the airplane over a century away.

Now the wheels and axles of countless locomotives; the base and cylinder of presses that form parts for the airplane maneuvering overhead; the castings and forgings that help power our ships, absorb recoil on anti-aircraft guns, and provide the track on which battleship turrets roll—may all come from Baldwin's Burnham plant. This plant is the direct descendant of Freedom Forge, now in its 150th year at the same location.

When you need dependable, quality forgings and castings for responsible jobs, this accumulated experience is waiting to serve you. Standardize on Standard. Baldwin Locomotive Works, Standard Steel Division, Burnham, Pennsylvania, U. S. A. Offices: Philadelphia, New York, Chicago, Washington, Boston, Cleveland, St. Louis, San Francisco, Houston, Pittsburgh.

BLW THE BALDWIN GROUP

BALDWIN

STEEL FORGINGS & CASTINGS

ALLOYS

of High Quality

When You Want Them

• Telephone, telegraph or write your requirements . . . any quantity . . . for shipment to conform to your production schedule. Every ton, every pound of unvarying quality, exactly to your specifications and delivered when you want them.

Last year NIAGARA FALLS SMELTING & REFINING CORP. helped American industry keep up to schedule by solving its alloy difficulties. By using our extensive research files and modern laboratory . . . *a service available to all* . . . the users of FALLS BRAND ALLOYS received the exact answer to their alloy problems and obtained the quality alloy they needed.

This year . . . right now . . . we have over 300 specific alloys available for prompt shipment. Our staff of research technicians are ready to start working on your alloy problems now.

Why sacrifice time or quality? Get both—Write or call today.

Our Telephone Number It's Buffalo Riverside 7812-3-4

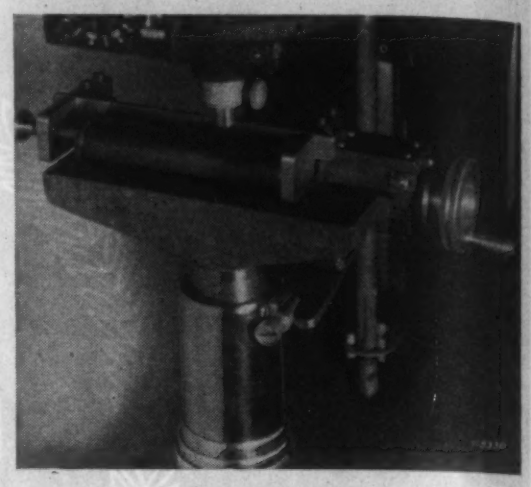
NIAGARA FALLS SMELTING & REFINING CORPORATION

America's Largest Producers of Alloys

BUFFALO 17, NEW YORK

Indexing Fixture for Jominy Bars

A new indexing fixture for Jominy hardenability bars has been developed by the *Precision Scientific Co.*, 1750 N. Springfield Ave., Chicago 47, in cooperation with J. T. Fergusson of Notre Dame University.



It mounts readily on either the Clark or Wilson hardness testing machine.

It comprises a heavy rigid base casting, indexing screw and quick return mechanism. The plug, which supports the fixture in the hardness tester, is tool steel, projects upwards through the base casting, and forms the surface against which the diamond point presses against the Jominy bar.

The screw operating the carriage back and forth is stainless steel, turned by a brass, chrome-plated hand wheel. A bronze half nut is fastened to a quick release lever engaging the screw. When the test bar has reached the end of its travel, the half nut is released and the entire carriage slides back rapidly to the new starting position. An adjustable stop automatically provides the initial starting point on the test bar. A spring plunger holds the test bar into position and allows enough freedom for the bar to rest firmly on the hardened steel nut.

Rotating Hearth Forging Furnace

A rotating hearth forging furnace with depressed roof and center venting stack has been brought out by the *Johnston Mfg. Co.*, 2825 E. Hennepin Ave., Minneapolis 13. Waste gases can escape from the furnace chamber at hearth level.

This is an improvement over the stack built up on the center of the table where a large part of the gases are vented at the top center of the furnace roof at 3000 F., the remainder leaving the bottom center part of the furnace chamber through "silo" vents at 2300 F.

The new style carries all vent gases away at 2300 F., resulting in a 25% saving of fuel, either gas or oil. Hottest gases are brought in contact with the stock.

The depressed roof forms a ring-type furnace chamber allowing better control over the entire heating range by zoning the chamber, and no heating space is lost. This construction eliminates the troublesome inside sand seal and permits a radial center bearing to hold the table in position.

Operating costs are reduced by elimination of shut downs for repairs to side wall vents or silos.

Sulphite-Treated
Alloy and Special Steels

BENEFITS TO USERS

- ✓ 25% Greater Machining Speed
- ✓ 200% Longer Tool Life
- ✓ Fewer Rejections
- ✓ More Uniform Physical Properties
- ✓ Fewer Operations
- ✓ Better Finished Product

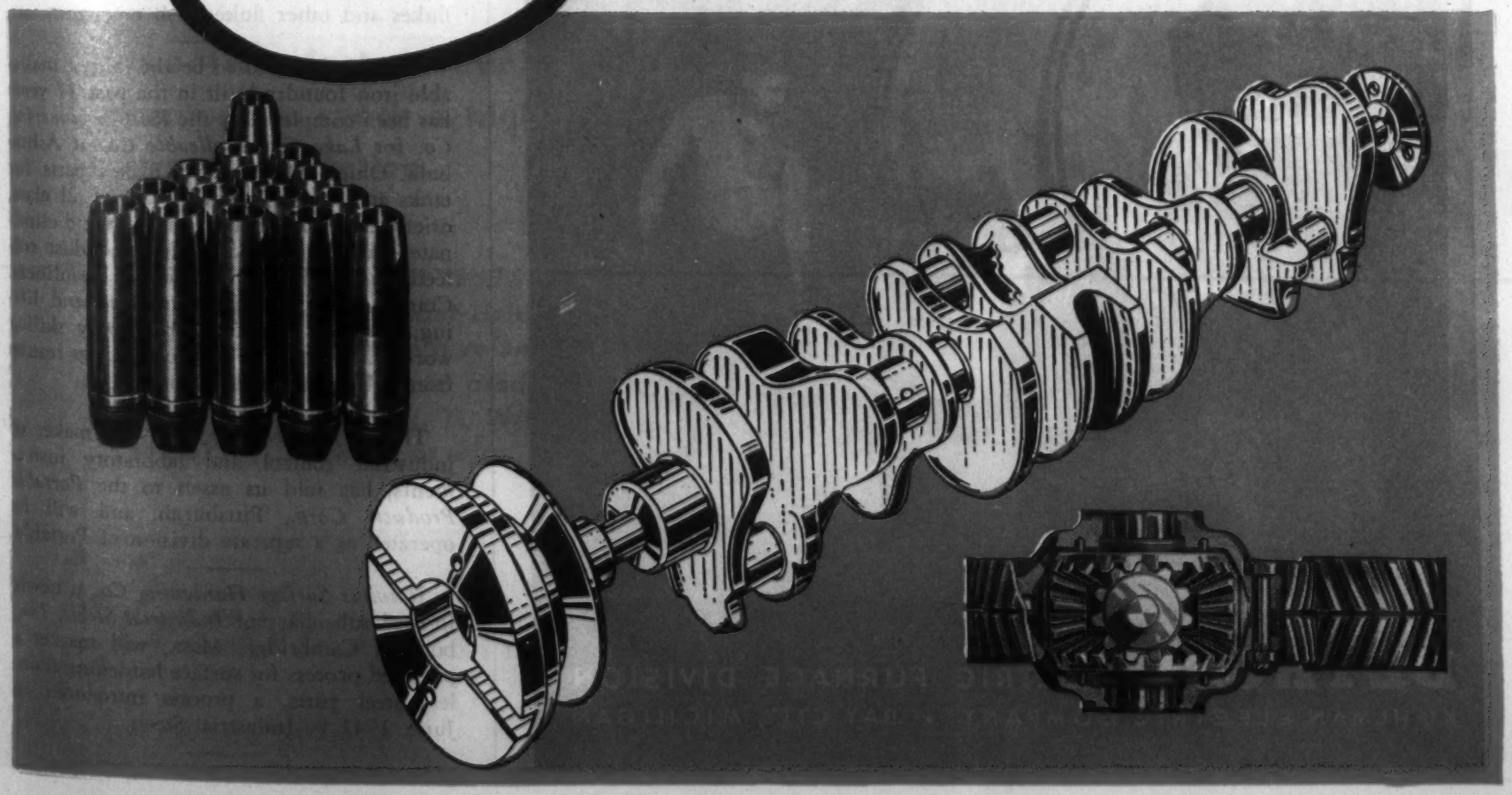
SULPHITE-TREATED alloy and special steels, which we have produced for a number of years, have solved many problems for steel users. They have been most satisfactorily applied where machinability is of first importance.

Sulphite treatment can be applied to most types of steel. It has been used successfully in the production of shells, crankshafts, camshafts, axles, and gears.

If you believe that your company may have an application for sulphite-treated steels, our sales and metallurgical staffs are at your service. We have accomplished satisfactory results for others and are ready to serve you in the same way.

WISCONSIN STEEL COMPANY

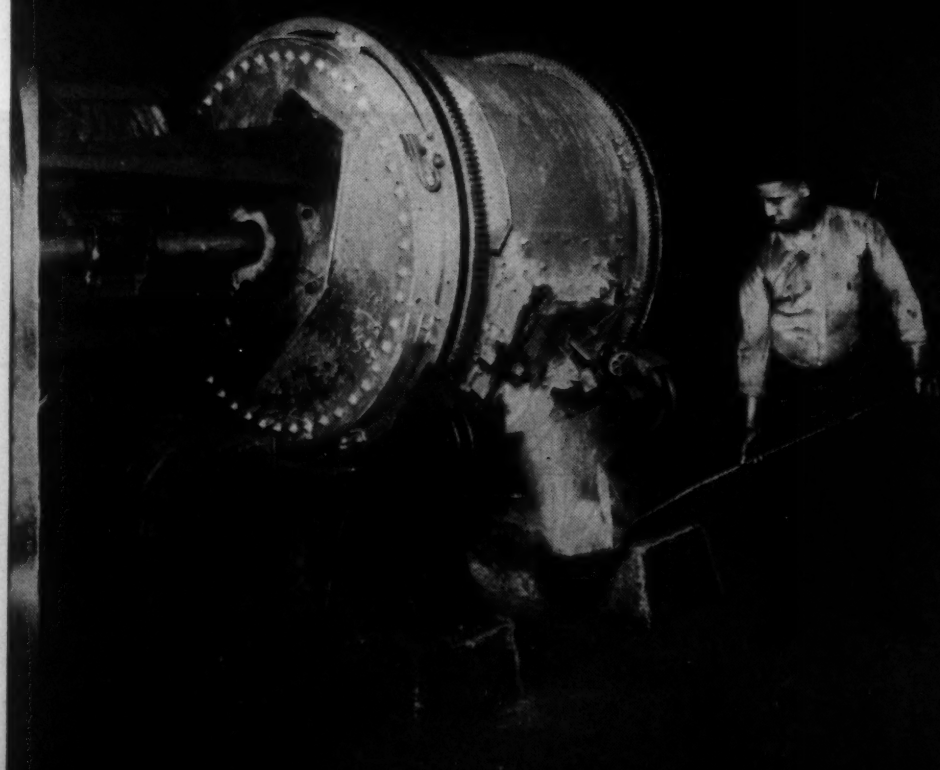
Affiliate of International Harvester Company
General Offices: 180 North Michigan Avenue, Chicago 1, Illinois



"Our metal losses run between .4% and .5% with a Detroit Rocking Electric Furnace"

A Foundry producing intricate bronze parts with a Detroit Rocking Electric Furnace Wrote recently, "Our principal alloy is 78-79% copper 2½% tin, 10% lead, 8-9% zinc, 0.5% nickel. Tests consistently showed the metal losses during melting run between .4% and .5%."

Records in scores of foundries show similar low metal losses and many other advantages. Detroit Electric Furnaces require less labor and produce more pounds of perfect castings per man-hour. They produce as many as 8 ferrous or 16 non-ferrous heats in one eight-hour day. Because they allow precise metallurgical control of any formula, Detroit Furnaces assure superior metallurgical results. Built in capacities from 10 to 8,000 lbs. Write today for further facts.



DETROIT ELECTRIC FURNACE DIVISION
KUHLMAN ELECTRIC COMPANY • BAY CITY, MICHIGAN

● An improved Duralite safety goggle is announced by *American Optical Co.*, Southbridge, Mass. A newly designed eyecup is considerably larger in area and more face conforming than the previous cup, providing maximum eye protection, increased ventilation and greater comfort. Several styles and colors of lenses are provided in this No. 301-A goggle.

Plants and Slants

Instead of conventional gray and buff for plants and equipment, the new Color Dynamics theory substitutes colors with wave lengths which quickly bring to the worker's eye the critical or operating parts of machines and others to "drop back" the less important ones, but provide the quickest rest for the eye. Sponsored by the *Pittsburgh Plate Glass Co.*, the system reduces accidents, decreases absenteeism, increases production and reduces scrap. Continued eye strain from conventional coloring methods leads to nervous tension, and drab surroundings encourage mental depression. Machine sections are painted in different, but not too widely contrasting colors. Walls are painted in "eye-rest" colors. A green, called "Vista," is most restful.

The medical department of *Inland Steel Co.* has furnished the company's physicians with a complete analysis of tropical, Asiatic and similar diseases to which a soldier returned to civilian life might have been exposed. The list describes 55 different ailments, encountered in 207 regions throughout the world to help stricken soldiers return to health and employment. Among diseases listed are endemic typhus fever, relapsing fever, rat bite fever, cholera, seven-day fever, sandfly fever, leprosy, intestinal flukes and other flukes, fish tapeworm, etc.

What is believed to be the largest malleable iron foundry built in the past 17 years has been completed by the *Rust Engineering Co.* for *Lake City Malleable Co.* at Ashtabula, Ohio. The foundry makes parts for tanks and trucks. Sidewalls are of all glass, oriented to admit maximum light and eliminate glare. Air conditioning and dust collection systems assure unusual cleanliness. Cranes and monorails eliminate hand lifting, allowing employment of only skilled workers. A constant flow of castings results from a bottleneck-less plant.

The *C. J. Tagliabue Mfg. Co.*, maker of industrial control and laboratory instruments, has sold its assets to the *Portable Products Corp.*, Pittsburgh, and will be operated as a separate division of Portable.

Stainless Surface Hardening Co., a newly formed subsidiary of *Industrial Steels, Inc.*, both of Cambridge, Mass., will market a patented process for surface hardening stainless steel parts, a process introduced in June, 1941 by Industrial Steels.

THIS WHEEL ADDS 48 MINUTES TO AN 8 HOUR SHIFT

Electro **Grinding Wheels make a 10% gain in cutting time with plant to plant regularity as they are adopted as standard. Greater gains often are reported.**

The reasons are two: (1) the structures developed make ELECTRO Grinding Wheels cut faster; and (2) the type of abrasive grain used is selected for fast cutting while retaining durability.

These two factors enable the operators to reach a higher unit hours of production.

ELECTRO Engineers are ready to present proof in your plant as well as to help accomplish both volume and quality gains on your production. Just phone Buffalo, N. Y., WAshington 5259...or, write or wire.

Tougher and more Durable

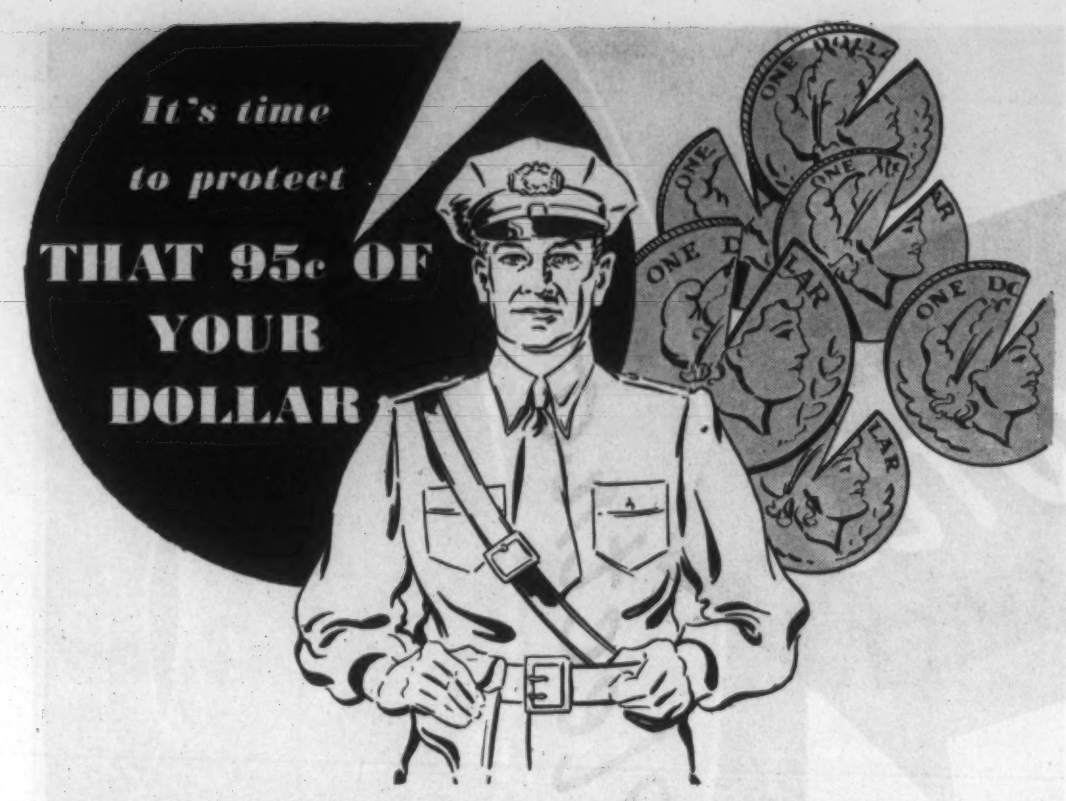
RUGGEDLY CONSTRUCTED and HEAT RESISTANT

K-302

Electro-REFRACTORIES & ALLOYS CORPORATION

MFRS. • CRUCIBLES • REFRACTORIES • STOPPERS • ALLOYS • GRINDING WHEELS

344 DELAWARE AVENUE — *Established 1919* — BUFFALO 2, NEW YORK



IT was good business in peacetime to use; wherever possible, metal cleaning materials that not only did the job for which they were intended — but which also saved in labor costs. It has been estimated that 95c of every cleaning dollar goes for labor. In time of war, with manpower shortages, these cost saving practices have proved *vital.*

A generation of experience in metal cleaning research and plant production requirements is now available through the facilities of the Optimus Detergents Company. This brings to the metal working industries an extension of the use of such labor saving and quality producing practices.

Trained in meeting rigorous standards of thoroughness, our technical staff is in a position to make practical recommendations pointing toward the application of the *right* process and the *right* detergent to accomplish the sought-for economies and result. Dependable OPTIMUS DETERGENTS* are the tools which are used to carry these labor saving methods to maximum effectiveness.

Write today for details as to how these processes and "tools" can be put to work saving labor in your plant.

Let Dependable

OPTIMUS DETERGENTS

and Processes Solve Your Problems in These and Other Related Operations

Cleaning metal before finishing
Preparation for welding
Ball Burnishing
Stripping for refinishing
Cleaning for Maintenance and Inspection

* * *

In Hand or Machine Operations
In Metal Washing Equipment
Cold or Heated Tanks
Steam Cleaning Machines
Spray, Dip or Soak Operations

Send for your copy of new Bulletin 4D1 and Optimus Cleaning Survey.

*Available in Alkaline, Acidic, Solvent and Emulsion Types.

OPTIMUS
DETERGENTS COMPANY
MATAWAN · NEW JERSEY

Manufacturers of
DETERGENTS for INDUSTRY

The *Duraloy Co.*, Scottdale, Pa., has purchased from the *United States Pipe & Foundry Co.*, Burlington, N. J., its interest in the Duraloy Co.

Advance Pressure Castings, Inc., die casters of Brooklyn, N. Y., has bought the building at 30 Wythe Ave., which adjoins their present plant, thereby adding 40,000 sq. ft. of floor area.

General offices of *Detroit Mold Engineering Co.*, formerly at 4835 Woodward Ave., Detroit, have been consolidated at the factory at 6686 McNichols Road, Detroit 12.

N. M. Salkover has disposed of interests with *Queen City Steel Treating Co.* and *Cincinnati Mine Machinery Co.* to devote full time to *Salkover Metal Processing*, which specializes in commercial electric furnace copper brazing and bright annealing, with offices in the Dixie Terminal Bldg., Cincinnati. He foresees greatly increased use of controlled atmosphere copper brazing after the war.

A post-war aluminum refrigerator car, 18,000 lb. lighter than standard cars, has been designed by *Reynolds Metals Co.* With the ice bunker under the car, center of gravity will be lower than in standard cars.

Despatch Oven Co., Minneapolis 14, has moved into an ultra modern office building, 70 by 80 ft.

U. S. Steel will invest at least $50,000,000 in post-war improvements to its Gary mills.

News of Engineers

Arthur L. LaMasters, formerly general manager and chief engineer, Claud S. Gordon Co., Chicago, has become vice president in charge of operations, Alloy Casting Co., Champaign, Ill. He has equipped, laid out and installed many large and modern heat treating departments of war plants.

James C. Hartley has been made director of research, Heppenstall Companies. He has been on the research staff of Crucible Steel Co., has maintained his own metallurgical consulting office, and has taught that subject. He has been chief metallurgist for Aluminum Forgings, Inc., Erie, Pa. He is the inventor of 35 patents pertaining to metallurgy.

E. I. Valyi has resigned as vice president of Sam Tour & Co., Inc. and has joined A.R.D. Corp., New York, applied research and development.

Dr. Martin de Simo has been made vice president in charge of research and development of the Great Lakes Carbon Corp., Chicago, which company he joined in 1941, organizing research and building the central laboratories.

Clarence F. Alban has been promoted from chief metallurgist to chief engineer of

Dotted outline shows hub before upsetting.

Aluminum Propeller Output INCREASED 55% with TOCCO Induction Heating

A LARGE manufacturer of automotive and aircraft parts reports these improvements in the heating for upsetting of aluminum propeller hub flanges for many of our fighters and bombers, including the B-29 Superfortress:

The former batch heating method—hot, dirty, cumbersome and non-uniform—required 2½ hours to heat the hubs. Total output averaged 45 per hour.

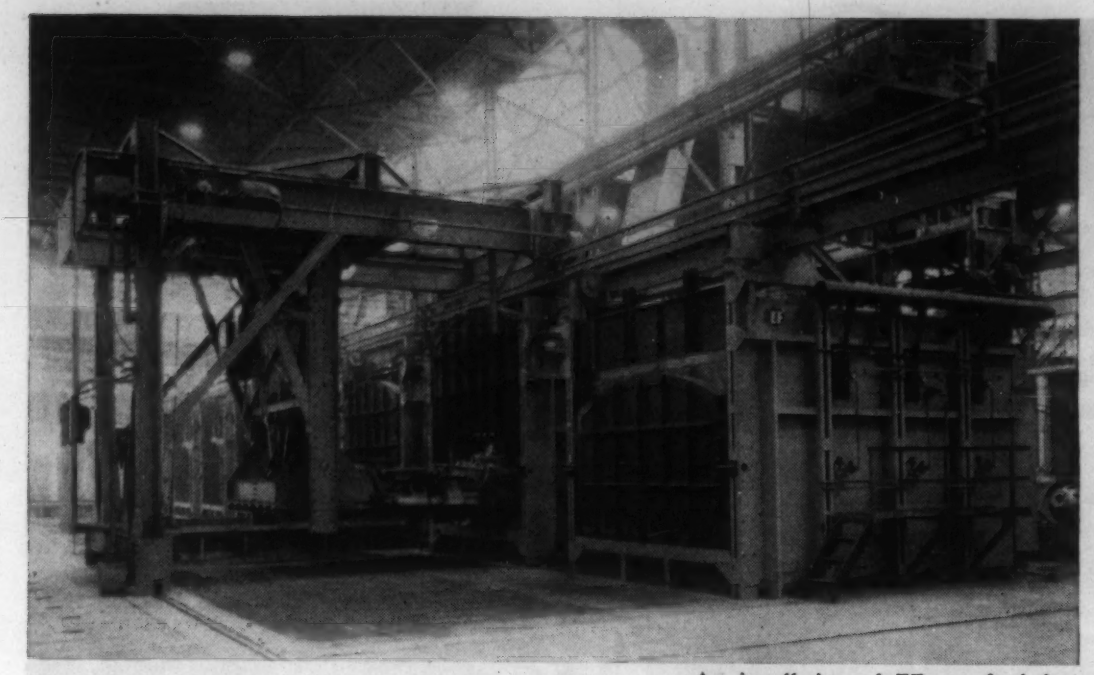
The 5-station TOCCO Induction Heating machine shown above—compact, clean, cool and accurate—heats 9″ of the 5¼″ diameter hubs to 800-850° F. uniformly throughout both length and cross-section. Every 47½ seconds, a prop is ready for the upsetter which is shown at the left of the TOCCO machine. Output of this one TOCCO unit averages 70 per hour . . . 55% faster than former method.

Find out how TOCCO can speed up your war production . . . improve your products and working conditions . . . cut your postwar costs. Write for free copy of "Results with TOCCO".

THE OHIO CRANKSHAFT COMPANY • Cleveland 1, Ohio

TOCCO

INDUCTION
HARDENING . . BRAZING
ANNEALING . . HEATING



An installation of EF gas fired furnaces with quench and gantry crane for various annealing and heat treating cycles on large parts and products.

For Production Furnaces

For Handling Any Size Parts or Products

FURNACES OIL, GAS or ELECTRIC

For Every Heating and Heat Treating Process

Aluminum Brazing
Annealing
Billet Heating
Bright Annealing
Bright Hardening
Copper Brazing
Controlled Atmosphere
Carburizing
Drawing
Enameling
Forging
Hardening
Malleablizing
Silver Soldering
Nitriding
Normalizing
Soaking Pits
Scale-Free Hardening
Quenching Machines
Ceramic Kilns, etc.
Process Heating

ELECTRIC FURNACES FUEL FIRED

We Build the Furnace to Fit Your Job

THE ELECTRIC FURNACE CO.

SALEM, OHIO

Consult EF Engineers

No Job Is Too Large or Too Unusual

Scale-free, uniformly annealed castings are discharged continuously from the EF special atmosphere furnaces shown below.

W. M. Chace Co., maker of thermostatic bimetals and special alloys. *H. D. Matthews,* who has been with the company over ten years has been made consulting engineer. He has written several technical articles on the application of thermostatic bimetals.

A. R. Stargardter has been made chief metallurgist of Ajax Electric Co., having previously held the same position with Eastern Stainless Steel Corp., Baltimore. Prior to that he was chief metallurgist with Gillette Safety Razor Co.

R. W. Waring has resigned from Sperry Gyroscope Co., Inc. to become chief engineer, East Main Plant, Bridgeport Brass Co., Bridgeport 2, Conn.

James H. Baldrey has been appointed superintendent of the melting department of Allegheny Ludlum Steel Corp., succeeding *T. F. McClester,* who is retiring after 20 years in that position. *Edward J. Doyle* has been made superintendent of the hammer shop, replacing *W. H. White,* retiring after 25 years in that position.

Joseph S. Brady has been made technical supervisor, Optimus Detergents Co., Matawan, N. J., maker of metal cleaners. Previous experience was with Eastman Kodak Co. and Oakite Products, Inc.

Everett C. Hite has become combustion and refractories engineer in the steel mill metallurgical department, Timken Roller Bearing Co., Canton, Ohio, having been assistant engineer, same department. His college education, experience and technical society membership have involved ceramics.

Dr. D. Gardner Foulke, recently chief chemist for the Garfield Div., Houdaille-Hershey Corp., has joined Foster D. Snell, Inc. as director of the analytical department. In his early career he was a college professor, later becoming assistant chief chemist with Republic Steel Corp. He has written several technical articles, including those dealing with electroplating baths.

Alexander Gobus and Charles Davidoff have been elected vice presidents of *Sam Tour & Co., Inc.,* New York. Dr. E. I. Valyi, formerly vice president, and Fred J. Tobias, formerly production engineer, are no longer with the company. *Met-Chem Processes, Inc.,* a Sam Tour & Co., Inc. affiliate, is in process of dissolution.

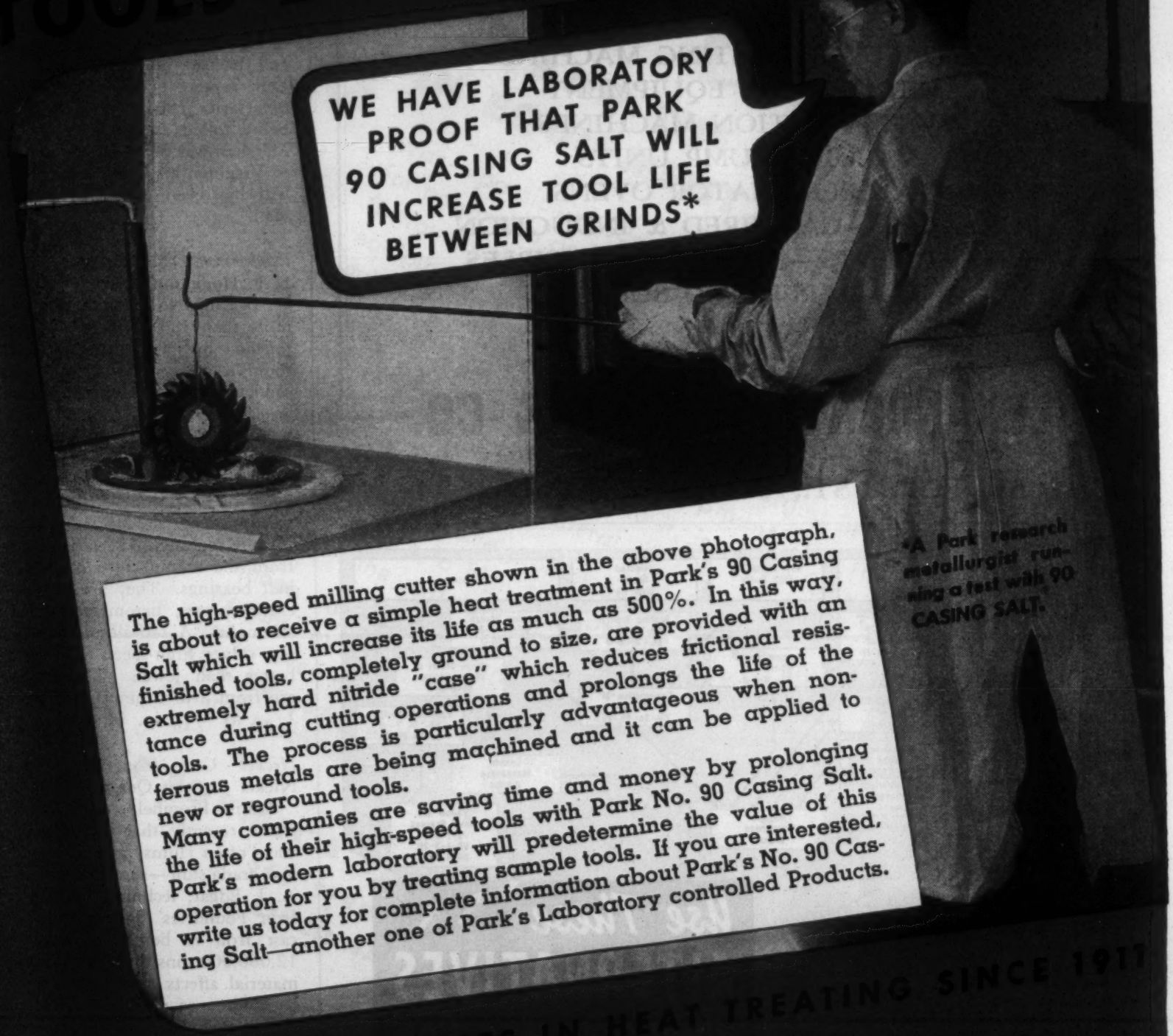
House Organ Notes

Chrysler Tonic, Chrysler Corp., Dec. 12, 1944.

Sodium-cooled valves, now used in airplanes, military tanks, etc. may be used in the post-war automobile for they are efficient in dissipating heat rapidly. The valve stem is hollowed out and 60% of the space filled with metallic sodium, which conducts heat at three times the rate of steel. Thus, the valve can operate under a peak load with high octane fuel without the valve heads reaching critically high temperatures. At 207 F. the sodium becomes liquid and, due to the rapid reciprocation

Park

90 Casing Salt GIVES YOUR TOOLS LONGER LIFE



*A Park research metallurgist running a test with 90 CASING SALT.

The high-speed milling cutter shown in the above photograph, is about to receive a simple heat treatment in Park's 90 Casing Salt which will increase its life as much as 500%. In this way, finished tools, completely ground to size, are provided with an extremely hard nitride "case" which reduces frictional resistance during cutting operations and prolongs the life of the tools. The process is particularly advantageous when non-ferrous metals are being machined and it can be applied to new or reground tools.

Many companies are saving time and money by prolonging the life of their high-speed tools with Park No. 90 Casing Salt. Park's modern laboratory will predetermine the value of this operation for you by treating sample tools. If you are interested, write us today for complete information about Park's No. 90 Casing Salt—another one of Park's Laboratory controlled Products.

★ SPECIALISTS IN HEAT TREATING SINCE 1911

Park
PARK CHEMICAL CO.
DETROIT, MICHIGAN

● Liquid and Solid Carburizers ☆ Cyanide, Neutral and High Speed Steel Salts ☆ Lead Pot Carbon ☆ Charcoal ☆ Coke ☆ No Carb. ☆ Carbon Preventer ☆ Quenching and Tempering Oils ☆ Drawing Salts ☆ Metal Cleaners ☆ Liquid Grain Cement

MILITARY AVE. DETROIT, MICH.

PRECISION CASTING EQUIPMENT AND SUPPLIES

For Complete Installations
Lost Wax—Investment Molding Process

•

CENTRIFUGAL CASTING MACHINES
METAL MOLD EQUIPMENT
WAX INJECTION MACHINES
VACUUM PUMP UNITS
WAX ELIMINATOR OVENS
FURNACES — GAS FIRED & INDUCTION
INVESTMENTS — WAXES — CRUCIBLES
AND ALL RELATED SUPPLIES

•

ALEXANDER SAUNDERS & CO.

Successor to J. Goebel & Co. — Est. 1865
95 BEDFORD ST., NEW YORK CITY 14

NOTE

•"Proper Melting Decreases Foundry Losses," contains interesting data. Also, the booklet, "Nonferrous Ingot Metals of Today." Write for both of these. They are free.

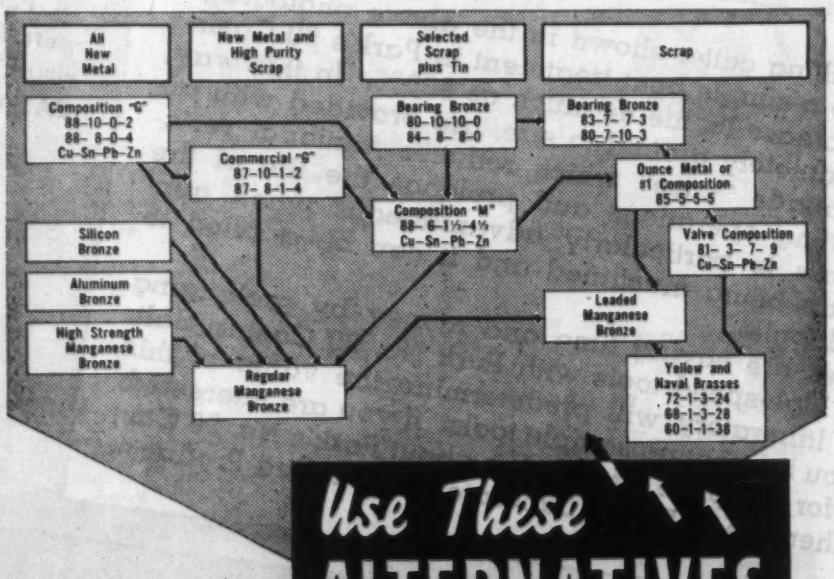
•

Send for booklet
"INGOT METALS OF TODAY"

•

16 STANDARD INGOT METALS BY AJAX

Ajax Tombasil
Ajax Plastic Bronze
Ajax Anti-Acid Bronze
Ajax Phosphor Bronze
Ajax Red Brass Ingots
Ajax Manganese Bronze
Ajax High-Tensile Manganese Bronze
Ajax Golden Glow Yellow Brass
Ajax-Hamilton Gear Bronze
Ajax Nickel-Copper 50-50%
Ajax Manganese Copper
Ajax Aluminum Alloys
Ajax Phosphor Copper
Ajax Silicon Copper
Ajax Nickel Alloys
Ajax Phosphor Tin



Use These **ALTERNATIVES** *Wherever You Can*

Notice how the arrows on the W.P.B. chart point to the *right*. . . . They show how alternative materials *currently available* can be utilized by foundrymen as now permitted by many designers. The purpose is to conserve primary metal at the mine through increased use of secondary ingots. Sometimes great ingenuity is called for, yet remember this:
The first program for scientific control of ingot metal was set up by Ajax 46 years ago. The result has been metal and practical technical follow-through in which Ajax increases your production by reducing rejects.

THE AJAX METAL COMPANY
ESTABLISHED 1880 PHILADELPHIA

ASSOCIATE COMPANIES:
AJAX ELECTRIC FURNACE CORP. Ajax-Wyatt Induction Furnaces for Melting
AJAX ELECTROTHERMIC CORP. Ajax-Northrup High Frequency Induction Furnaces
AJAX ELECTRIC CO., INC. The Ajax-Hultgren Electric Salt Bath Furnace
AJAX ENGINEERING CORP. Ajax-Tama-Wyatt Aluminum Melting Induction Furnaces

in carrying the heat from the head to the stem. Often a Stellite valve face is used to combat the higher combustion chamber temperatures, resisting abrasion, warping and pitting. Silchrome steel is frequently used in the intake valves.

The Stabilizer, Lincoln Electric Co., Dec.-Jan. 1944-45.

In view of the proposal to repair the famous Liberty Bell so that it may ring out over the radio the news of Germany's defeat, it is appropriate to review the bell's history. The original bell had to be recast when it cracked during a tone test. The second bell, implemented with American copper to make it less brittle, alsb proved defective and had to be recast. The third Liberty Bell, repeatedly rung on festivals and anniversaries, cracked on July 8, 1835, while being tolled as the body of Chief Justice Marshall was being taken from Philadelphia to Virginia, his native state. Since then the bell has been enshrined in Independence Hall.

Production Data from the Houghton Line, E. F. Houghton & Co., Jan. 1945.

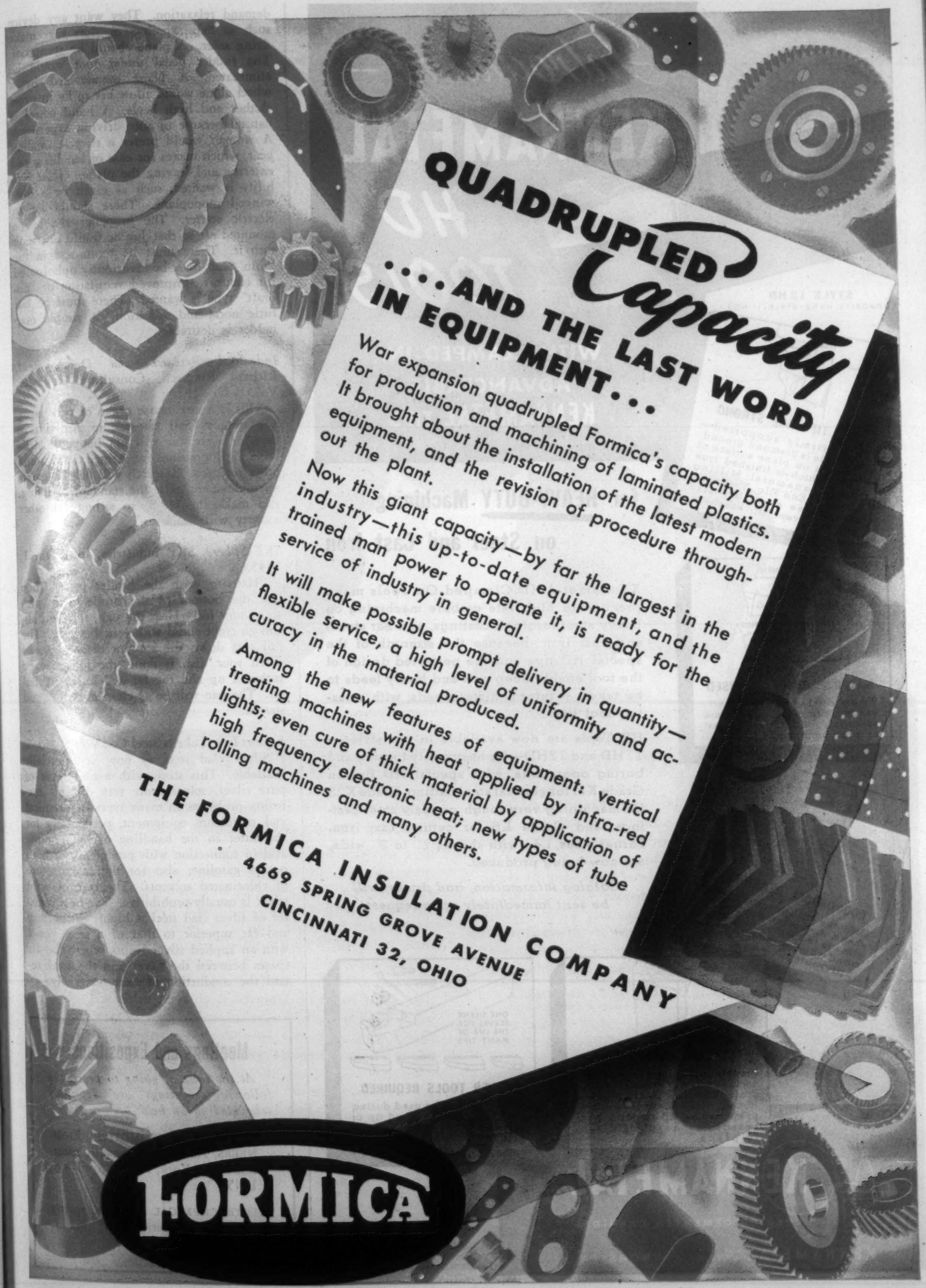
"Bearings so small a thimble will hold more than 300 of them. . . Bearings never touched by hand, made in air-conditioned rooms so no speck of dust or drop of moisture can harm them. . . Bearings made of 52100 steel or beryllium [copper], with tolerances held to 0.0002 in. . . . the largest only $^{5}/_{16}$ in. O.D. That is a precision job indeed, requiring precision instruments and the finest of lubricants, cutting fluids and heat treating materials. Miniature Precision Bearings, Keene, N. H., has built a business from the manufacture of these Lilliputian ball bearings. They are used in recorders, chronometers, barometers and aircraft instruments. A self-aligning pivot-type bearing solves high-speed and shock exposure better than jewels. These pivot bearings are from 2 to 5 mm. O.D., the balls being $^{1}/_{64}$ to $^{1}/_{16}$ in. in diam.

Nickel Cast Iron News, International Nickel Co., 1st Quarter, 1945.

Louis Bromfield, well known author, wrote recently that agricultural machinery was "often clumsy and made of cheap and low grade stuff—sometimes mere cast iron." A. J. Edgar, technical adviser to the Gray Iron Foundries' Society, answered: "Mere cast iron is being used at the rate of 12,000,000 tons this year. This engineering material affects more applications in industry and more every day life than the sum of other engineering materials except steel. Gray iron castings are used in the heads and block of trucks, jeeps, landing barges and tanks. They tried higher priced materials but went back to gray iron."

The Pegasus, Fairchild Engine & Airplane Corp., Feb. 1945.

Women are recognized as the principal buyers of goods used by the family. Automobiles are designed chiefly with the woman's tastes in mind. Many recognize that the future airplane will be designed with women's wishes in the fore. Sally Knapp writes under topic of "Family Plane to Reflect Women's Needs," after having consulted aviatrix and other women. Safety is their first requisite in an airplane. They

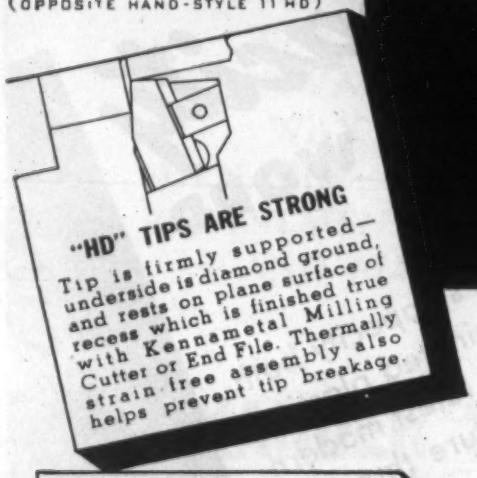

QUADRUPLED Capacity
...AND THE LAST WORD IN EQUIPMENT...
War expansion quadrupled Formica's capacity both for production and machining of laminated plastics. It brought about the installation of the latest modern equipment, and the revision of procedure throughout the plant.
Now this giant capacity—by far the largest in the industry—this up-to-date equipment, and the trained man power to operate it, is ready for the service of industry in general.
It will make possible prompt delivery in quantity—flexible service, a high level of uniformity and accuracy in the material produced.
Among the new features of equipment: vertical treating machines with heat applied by infra-red lights; even cure of thick material by application of high frequency electronic heat; new types of tube rolling machines and many others.
THE FORMICA INSULATION COMPANY
4669 SPRING GROVE AVENUE
CINCINNATI 32, OHIO
FORMICA

Introducing —

KENNAMETAL "HD" TOOLS

WITH CLAMPED-IN, ADVANCEABLE KENNAMETAL TIPS

STYLE 12 HD
(OPPOSITE HAND-STYLE 11 HD)



"HD" TIPS ARE STRONG

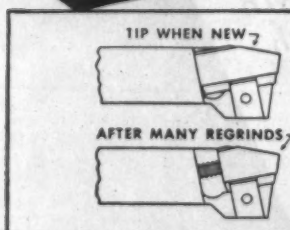
Tip is firmly supported—underside is diamond ground, and rests on plane surface of recess which is finished true with Kennametal Milling Cutter or End File. Thermally strain free assembly also helps prevent tip breakage.

for HEAVY-DUTY Machining on Steel and Cast Iron

Kennametal HD Clamped-On Tools make practicable high rate carbide machining on heavy steel forgings, castings, and bar stock, and cast iron, because the strength of the special HD tips and the perfected design of the tool enable deep cuts and heavy feeds to be taken at intermediate speeds, with amazing tool life.

HD Tools are now available in two styles—11HD and 12HD—for heavy duty turning and boring operations, with special HD tips in Grade KM for general steel cutting, Grade K2S for machining very rough or scaly steel castings, and Grade K6 for cutting cast iron. Larger sizes, i.e., with shanks 1" to 2" wide, are now being produced.

Catalog information, and prices, will be sent immediately upon request.



MAJOR PART OF TIP USED

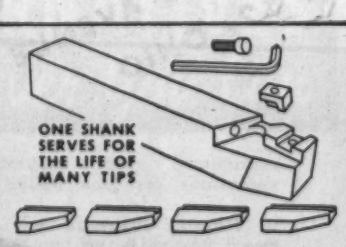
When dull, tip can be advanced, and resharpened time and again, until the major part of it has been used.

ECONOMICAL REGRINDING

Only the tip is reground—no shank steel is removed. Operation is fast—clogging of diamond wheel grinder with steel is prevented.

STREAMLINED DESIGN

Smooth, unimpeded chip flow assured by improved clamping arrangement, correctly positioned. HD design employs pressures set up in cutting as factors to help hold tip in place.



FEWER TOOLS REQUIRED

Many tips can be used during the life of a shank, and tip of suitable Kennametal composition can be used for each job.

KENNAMETAL

SUPERIOR CEMENTED CARBIDES

TRADE MARK REG. U. S. PAT. OFF.

KENNAMETAL *Inc.*, LATROBE, PA.

demand relaxation. They want any device such as flaps, spoilers or slots that make flying safer. A plane should be spinproof. The rudder pedal under foot would be eliminated. A plane maneuvered by a wheel alone would allow her to fly in street clothes and high heels. A hand wheel is natural because of auto driving experience. A woman would prefer a tricycle landing gear, which makes for ease of handling and entering and leaving the plane. Great visibility is wanted, such as given by a low-winged monoplane. There should be an electric starter. The propeller should be mounted aft so that Junior would not walk into it. There must be roominess in the cabin. Seats must be luxuriously upholstered for comfort. Improved ventilation of "no-draft" type is wanted. There must be but little noise and vibration. A simple map holder is desirable.

Industrial Research and Development, Richard Rimbach, Consulting Engineer, Vol. 1, No. 1.

This is a new house organ of two pages. We quote: "Sell research to America so that the next war will not happen. Make large appropriations for Armed Service and other research. Research will help alleviate unemployment, raise the standard of living, and make the U. S. so strong no other country will attack us."

SKF Sphere, SKF Industries, Inc., Jan. 1, 1945.

"Hate to wash the broiler pan? Then line the bottom of the broiler pan with aluminum foil. Heat the pan, foil and all, and go right ahead with your broiling. The foil cuts down the amount of smoke, and when your dish is done, the foil may be gathered up and the fat and juices poured off. The pan will be as clean as before you started."

Lukens Life, Lukens Steel Co., Vol. 6, No. 1.

Silver clad steel is now commercially available. This steel, with a clad layer of pure silver, solves some very difficult corrosion problems in many types of chemical and petroleum equipment, particularly for the latter in the handling of hydrofluoric acid in connection with production of high octane gasoline; also for the manufacture of chlorinated solvents. The cost of solid silver is usually prohibitive. The heat transfer of silver clad steel is highly satisfactory and far superior to that of a steel vessel with an applied silver lining where the air spaces between the silver and the steel retard the conduction of heat materially.

Meetings and Expositions

At the time of going to press, the following meetings are definitely scheduled to be held:—

SOCIETY OF AUTOMOTIVE ENGINEERS, National Aeronautic meeting. New York, N. Y. April 4-6, 1945.

ELECTROCHEMICAL SOCIETY, spring meeting. Atlantic City, N. J. April 12-14, 1945.

THIS IS WHAT HAPPENS WHEN YOU BATHE METAL

Correctly cleaning metal is no simple operation... these elements must go into action...

Wetting Action *(WA)* must lower surface and interfacial tensions and allow the cleaning solution to penetrate to surface of the base. Emulsifying Action *(EA)* must disperse grease and oil as tiny globules, and by suspension prevent redeposition. Saponifying Value *(SV)* must convert organic fats and oils into soluble soaps, and Solvent Action *(SA)* put soils into solution. Colloidal Activity *(CA)* must disperse solid soils into minute particles which may then be easily removed. Water Conditioning *(WC)* removes or controls the elements which cause water hardness.

Correct Buffer Index *(BI)* assures ability to absorb either alkaline or acid soil, thus prolonging efficiency of the solution. Proper *pH* assures the correct measure of energy of alkalinity and Total Alkalinity *(TA)* must supply maximum active cleaning energy.

In formulating a cleaning compound, therefore, it is obvious that no one factor is a magic key to all problems. The answer is in determining the relative value of *all* these factors as they apply to your problem.

Putting these factors into correct balance is a responsibility you can entrust to Turco chemists —a responsibility for which their two decades of Research and Experience *(RE)* have well qualified them. *Take your problem to Turco.*

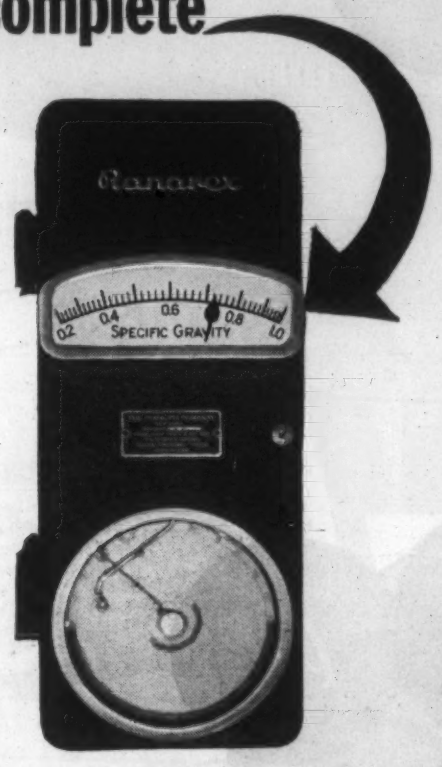
For a fuller explanation of these vital factors, write for Turco's Booklet on your firm letterhead, please.

TURCO

INDUSTRIAL CHEMICAL COMPOUNDS

TURCO PRODUCTS, INC. *Main Office and Factory:* 6135 S. Central Ave., Los Angeles 1, Calif. • *Southern Factory:* 1606 Henderson St., Houston 1, Texas • *Chicago Office and Factory:* 125 West 46th Street, Chicago 9 • *Offices and Warehouses in All Principal Cities*

Instrument tells exact moment when FURNACE PURGE is complete



MEASURE specific gravity of generator gas with the Ranarex* instrument and continue purge until the specific gravity is the same at the furnace outlet as it is at the inlet. At that point you can be sure there's no air in the gas. Danger of explosion is reduced and over-purging for safety is unnecessary.

Helps control quality

Ranarex also makes it easy to maintain uniform composition. Just measure the specific gravity of the raw gas and atmosphere gas. The instrument is quick, accurate, easy to use. It contains no chemicals or fragile parts.

Free booklet will be sent on request to The Permutit Company, Department A17, 330 West 42nd Street, New York 18, New York. In Canada: Permutit Company of Canada, Ltd., Montreal. *Trademark Reg. U. S. Pat. Off.

PERMUTIT'S
RANAREX

Briefs on Associations, Promotions and Education

A cooking grill, made of magnesium, resting on a pile of pure magnesium ingots was subjected to the flame of a blow torch for over 20 min. On the grill were spare ribs. The audience consisted of over 500 fire fighters attending the 17th annual fire department instructors conference in Memphis. The purpose of the demonstration was to show that magnesium in solid pieces does not burn. The demonstrator was Mrs. Connie O'Sullivan, wife of the Memphis fire chief. The affair was reported by Perry D. Helser, secretary of the Magnesium Assn. According to grapevine reports, there was more wonder concerning the presence of the spare ribs than in the fact that the magnesium did not burn.

The Metal Powder Assn. has elected Felix Edgar Wormser acting secretary and treasurer, and has moved its offices to 420 Lexington Ave., New York 17. Mr. Wormser holds a similar position with the Lead Industries Assn.

Civic bodies in the Pacific Coast are conducting a vigorous campaign to develop its new wartime steel plants into an industry that can survive in peacetime. A Steel Committee of the Western State Council has been formed, naming as chairman Leonard E. Read, general manager, Los Angeles Chamber of Commerce. The Council is composed of secretaries or general managers of chambers of commerce in eleven Far Western states and was formed in October, 1944. A steel conference scheduled for Feb. 12 and 13 at Salt Lake City is the first program meeting of the new Council. Attendance was to be limited to under 50 in line with new convention regulations.

The Midwest Research Institute has been formed at Kansas City, Mo. to cover the fields of chemistry, physics, metallurgy, minerology, biology, bacteriology; chemical, civil, electrical and mechanical engineering and other fields of science and science application. Harold Vagtborg, former director of the Armour Research Foundation, is the new president. There are 100 trustees, including well-known names, such as Charles F. Kettering.

A safety color code has been worked out by the American Standards Assn. An illustration is the code to identify materials flowing in pipes: Red, for fire protection equipment; orange-yellow, for dangerous materials; green, for safe materials; blue, for protective materials; purple, for extra valuable materials. One may obtain further details free by writing the Association at 70 E. 45th St., New York 17.

A sound film, depicting production and fabrication of magnesium, has been put out by Hills-McCanna Co., 3025 N. Western Ave., Chicago. Its title is: "A Tour of a Modern Magnesium Foundry."

The National Founders Assn. has elected as president Herman O. Menck, vice president and works manager, Harnischfeger Corp., succeeding D. C. Bakewell of Pittsburgh.

Robert J. Quinn, Mathieson Alkali

Applied like paint with a brush or gun

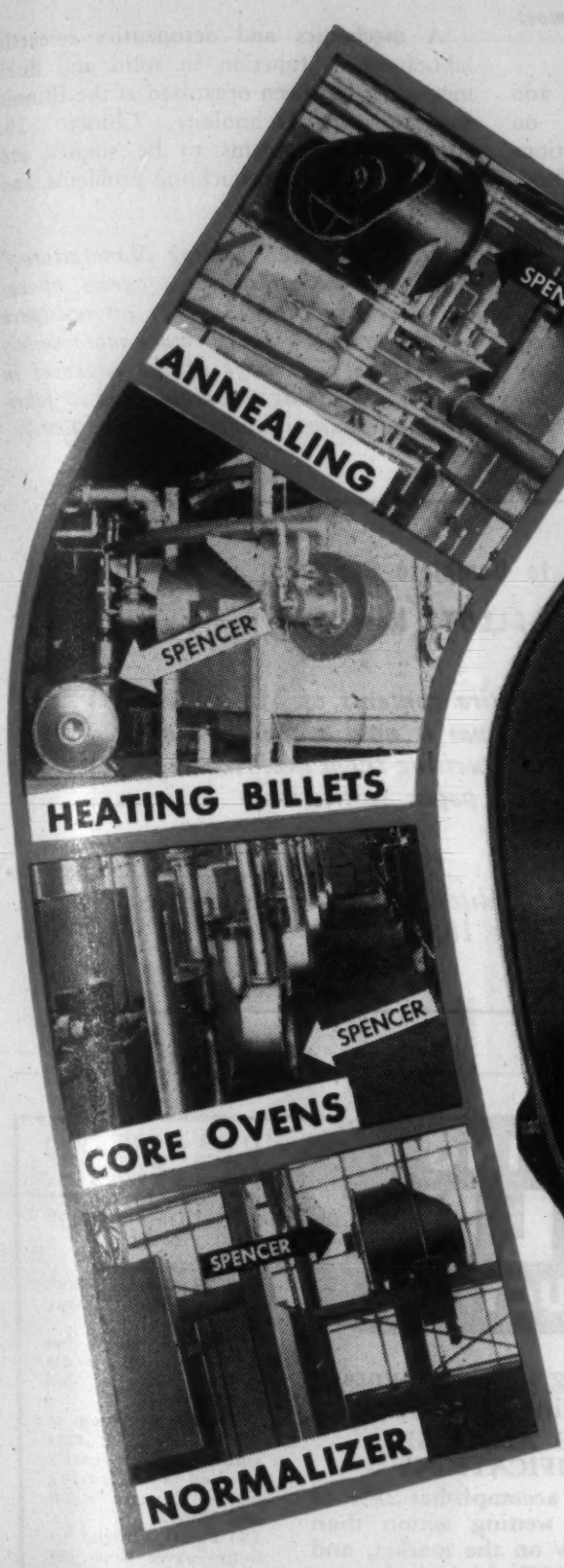
The highly-glazed surface produced and maintained with Brickseal is the secret of its unusual performance with any type of refractory.

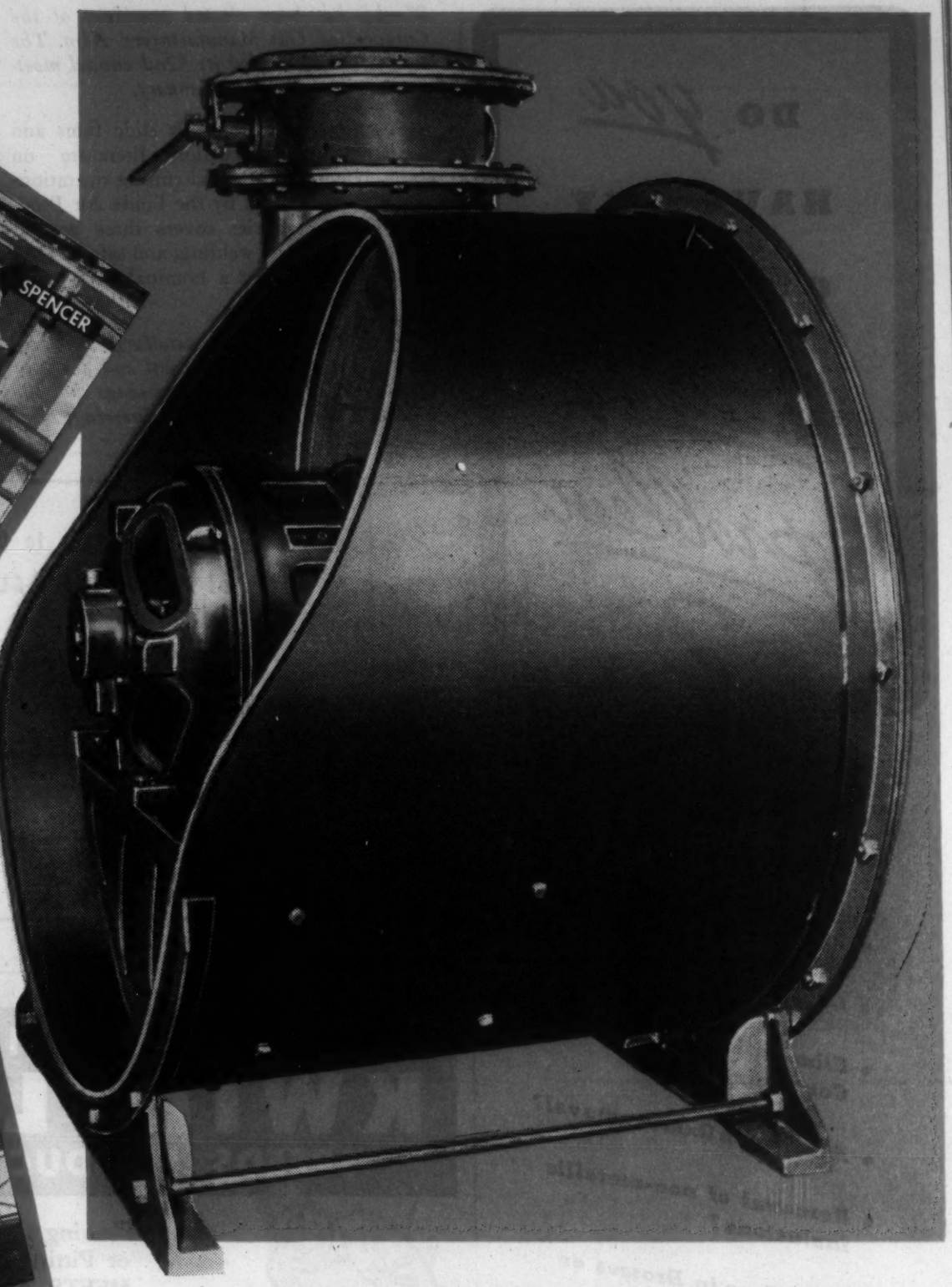
Unlike air-set washes, Brickseal consists of high-fusion clays and metal oxides combined in oil. Brickseal is applied with brush or gun, and the unit may be fired at once. Furnace heat burns off the oil and vitrifies the clays and metals, forming a highly-glazed, air-tight, monolithic coating integral with the refractory. At operating temperature Brickseal becomes semi-plastic so that it cannot crack, peel or blister due to sudden temperature variations.

The glazed Brickseal surface reflects radiant heat, and is immune to gases, acids, alkalis and unignited fuel. It fills old cracks and binds loosened brickwork. Clinkers and slag may be removed without damage to lining.

Brickseal assures you of longer refractory life, reduced maintenance, and more production with less fuel, all at very little cost. Write for Brickseal sample.

BRICKSEAL
REFRACTORY CO.
1029 CLINTON ST., HOBOKEN, N. J.





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STRESS RELIEVING
HEATING FOR FORGING
SPHEROIDIZING
HEAT TREATING GEARS
MELTING
BAKING PORCELAIN
BAKING CORES AND MOLDS
HEAT TREATING PARTS
HEAT TREATING TOOL STEELS

Select any industrial process involving oil or gas-fired equipment, and you will find that Spencer Turbos are prominent in that field.

Pick any one of the leading manufacturers of heat-treating equipment and you will find that Spencer Turbos have been their preference for many years.

The reasons: A simplicity of design—as simple as a fan, as sturdy as a bridge—with wide clearances and only two bearings to grease—plus automatic maintenance of pressure regardless of load.

These and many other facts are contained in the Spencer Bulletins and the Spencer Turbo Data Book—Yours for the asking.

THE SPENCER TURBINE COMPANY • HARTFORD 6, CONNECTICUT

257-C

TURBO-COMPRESSORS

Works, has been elected president of the Compressed Gas Manufacturers' Assn. The association concluded its 32nd annual meeting in Chicago in late January.

A series of how-to-do-it slide films and accompanying instruction literature on oxyacetylene welding and cutting operations has been completed by the Linde Air Products Co. The series covers three general subjects: Cutting, welding, and safety. They may be obtained at a nominal price from any Linde office.

Courses in powder metallurgy and research laboratory management and development are being offered evenings by the graduate div., College of Engineering, New York University. They are available to men in industry.

A mechanics and aeronautics research laboratory to function in solid and fluid mechanics has been organized at the Illinois Institute of Technology, Chicago 16. Among the problems to be studied are failure of materials, buckling problems, and airfoil problems.

The Resistance Welding Manufacturers' Assn. has inaugurated a program of cooperative educational activity on resistance welding subjects. It will make more widely available a knowledge of the advances in design, in welding techniques and in fabricating procedures made during the war.

Annual Index to Complete Contents of METALS AND ALLOYS Now Ready!

A complete Index to the entire contents of METALS AND ALLOYS *for all twelve 1944 issues is now available. Copies will be sent to all subscribers requesting them until the supply (which is limited because of paper restrictions) becomes exhausted.*

Address requests to Index Editor, METALS AND ALLOYS, *330 West 42nd St., New York 18, N. Y.*

DO *you* HAVE ANY OF THESE *melting problems* ?

- Oxidation of Metals?
- Absorption of Gases?
- Porosity in Castings?
- Low Physical Properties?
- Elimination of Aluminum Contamination?
- Aluminum Oxide removal?
- Removal of non-metallic inclusions?
- Metal-loss in Drosses or Slags?
- Lack of Fluidity?
- Pinholes, cracks, draws, etc.

If you DO, *write us!* There's a

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product for Aluminum Alloys . . . Brass . . . Bronze . . . Nickel Alloys . . . Aluminum Bronze . . . Manganese and Silicon Bronze . . . Grey Iron . . . that is eliminating these melting problems in the country's best - known foundries. Get the facts today.

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SUPER–WETTING
KWIKFLUX
SPEEDS PRODUCTION

Fast Flowing . . . No Lumping or Pitting of Solder
MEETS ALL RIGID SPECIFICATIONS

KWIKFLUX accomplishes 25% to 50% higher wetting action than the fluxes now on the market, and has almost 100% higher penetration in deep joints. It works perfectly with direct gas flame, hydrogen, acetylene—Muffle (direct or indirect) and induction heating.
KWIKFLUX is used for brazing, hard soldering and welding of Stainless Steel, Iron, Copper, Brass, Bronze, Platinum, Gold, Silver, Monel Metal, Nickel, German Silver and other ferrous or non-ferrous metals and alloys. It will not blacken brass or copper, and is suited to either automatic or manual operations. Fast, efficient action assures improved quality and finish.

TESTED AND PROVEN BY PROMINENT USER OF FLUXES
"KWIKFLUX has proven far superior to other fluxes due to the ease with which the excess material may be removed after brazing, that it is also necessary to use very much less quantity, and that it is much easier on the eyes, throat and hands." (Name on request)

WRITE FOR LITERATURE
Data sheets describing KWIKFLUX in detail — advantages, properties, characteristics and price—will be sent promptly on request. There is no obligation.

OUR NEW 1945 PRICE SCHEDULE PLACES KWIKFLUX ON AN ALL-INCLUSIVE COMPETITIVE BASIS

Advantages:
(1) Perfect with both Low and High Melting Point Hard Solders.
(2) Excess Flux washes off clear in hot water —saves cleaning and finishing time.
(3) Does not lump or pit solder. Forms smooth film easily washed off, leaving surface beneath bright and shiny.
(4) Faster, Fluxing Actions—saves time, gas and electricity.
(5) Fumes are fixed because KWIKFLUX is neutral. Increases production efficiency.

SEND FOR FREE TRIAL JAR
For more than 12 years, our tested research improvements have been passed on to our customers. This service has been in operation during the war period.

KWIKFLUX (Patented)

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